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ABSTRACT

These military-developed curriculum materials consist of four volumes of individualized, self-paced texts and workbooks for use by those studying to become aircraft pneudraulic repairmen. Covered in the individual volumes are the following topics: pneudraulic functions and career program (housekeeping and safety practices, hydraulic fluids and plumbing materials, and maintenance tools); operation and maintenance of pneudraulic components (pneudraulic terms; pneudraulic systems supply units; pressure-regulating, limiting, and controlling devices; flow control and directional units; landing-gear components; and brake systems components); pneudraulic systems and principles of operation (pneudraulic power systems, hydraulic actuating systems, and aircraft emergency pneudraulic systems); and ground equipment, schematics, and supervision and training (shop and aerospace equipment and the use of hydraulic schematics). Each chapter contains objectives, readings, review exercises keyed to the text, and answers to the exercises. (MN)

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
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- Conducting leadership development and training programs

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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
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Olympia, WA 98504
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1776 University Ave.
Honolulu, HI 96822
808/948-7834

AIRCRAFT PNEUDRAULIC REPAIRMAN

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AIRCRAFT PNEUDRAULIC REPAIRMAN

Correspondence Course 2-4

Developed by:

United States Air Force

Development and Review Dates:

September 1975

Occupational Area:

Aviation

Cost:

Print Pages:

439

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

None

Target Audiences:

Grades 10-adult

Organization of Materials:

Text; student workbooks with objectives, assignments, review exercises with answers, and volume review exercises

Type of Instruction:

Individualized, self-paced

Type of Materials:			**No. of Pages:**	**Average Completion Time:**
Volume 1	–	*Pneudraulic Functions and Career Program*	53	Flexible
		Workbook	27	
Volume 2	–	*Operation and Maintenance of Pneudraulic Components*	110	Flexible
		Workbook	41	
Volume 3	–	*Pneudraulic Systems and Principles of Operation*	66	Flexible
		Workbook	29	
Volume 4	–	*Ground Equipment Schematics and Supervision and Training*	58	Flexible
		Workbook	26	

Supplementary Materials Required:

None

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Course Description:

This course was designed as the theory portion to supplement on-the-job training to upgrade an Apprentice (semi-skilled) level repairperson to the Specialist (skilled) level. The specialist's duties fall in the following four areas:

- Performs preventive maintenance on aircraft and ground equipment pneumatic/hydraulic systems
- Installs and repairs aircraft and ground equipment pneumatic/hydraulic components
- Inspects pneumatic/hydraulic shop activities
- Supervises aircraft and ground equipment pneumatic/hydraulic repair personnel

Each volume is divided into chapters and accompanied with a workbook. Some sections were deleted because of references to specific military procedures or organization.

Volume 1 — *Pneudraulic Functions and Career Program* discusses good housekeeping and safety practices, hydraulic fluids and plumbing materials, and maintenance tools. The first three chapters dealing with Air Force organization and career programs, Air Force publications, and supply management and security were deleted.

Volume 2 — *Operation and Maintenance of Pneudraulic Components* contains six chapters covering pneudraulic terms; pneudraulic systems supply units, pressure-regulating, limiting and controlling devices; flow control and directional units; landing gear components; and brake systems components.

Volume 3 — *Pneudraulic Systems and Principles of Operation* contains five chapters discussing aircraft familiarization, principles of electricity, pneudraulic power systems, hydraulic actuating systems, and aircraft emergency pneudraulic systems.

Volume 4 — *Ground Equipment, Schematics, and Supervision and Training* contains chapters on shop and aerospace ground equipment and the use of hydraulic schematics. The third chapter on supervision and training was deleted because of references to specific military procedures and organization.

Each chapter contains objectives, readings, review exercises keyed to the text, and answers to the exercises. Volume review exercises are available, but no answers are provided. This course was designed for student self-study and evaluation while in a shop or on-the-job learning situation. It contains much basic information as well as some supervisory training.

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AIRCRAFT PNEUDRAULIC REPAIRMAN
(AFSC 42152)

Volume 1

Pneudraulic Functions and Career Program

Extension Course Institute

Air University

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Preface

THIS CAREER development course will help you qualify in the upgrade knowledge requirements for pneudraulic repairman specialty. This course deals with job-related areas for the pneudraulic repairman. It is the self-study portion of your on-the-job training program. It contains information required for your progression from the 3- to the 5-skill level.

Whereas this course should equip you to pass the speciality knowledge tests, you must still satisfy on-the-job proficiency requirements of your unit OJT program before you can advance in skill level. You must apply yourself and study to acquire this knowledge.

This course contains four volumes. The first volume deals with pneudraulic functions and career programs. The second covers the operation and maintenance of pneudraulic components. The third deals with pneudraulic systems and the principles of operation, and the fourth and final volume is concerned with ground equipment, schematics, and supervision and training.

This volume contains six chapters. The first chapter introduces you to the organization of maintenance activities and the Air Force career program. Chapter 2 deals with Air Force publication types and the technical order system. The next chapter details the responsibility for public property, principles of supply authorization and management, and the security system. In the fourth chapter you will learn about good housekeeping and safety practices, and Chapter 5 deals with hydraulic fluids and plumbing materials. Chapter 6, the final chapter of this volume, details procedures for the use of handtools, special measuring tools, the property of metals, and corrosion control. Each of these chapters is important to your career. After you have finished reading this volume, complete the volume review exercises. Then you will be ready to continue to Volume 2, which covers the operation and maintenance of the pneudraulic components.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TTOC), Chanute AFB, Ill 61868.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB, Alabama 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate, and current as of November 1971.

CHANGES FOR THE TEXT: VOLUME 1

PEN-AND-INK CHANGES:

Page	Paragraph	Line	Correction
79	16-37	2 & 3	Change "once a month" to "every two months."
79	16-37	5	Change "30" to "60."
79	16-37	8	Change "April" to "May."
83	17-9	16, 17 & 18	Delete.
85	17-15		After "ex-", add the following: ". . . tend through the center of the thimble and barrel and protrudes from the hole in the center of the base. The base provides a sur- . . ."

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MODIFICATIONS

Pages 1– 39 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

Good Housekeeping and Safety Practices

SAFETY, SAFETY, safety! You have heard it before and you will hear it again. So what? Just ask yourself, what does it do for me? That is a fair question and deserves a fair answer. Would you accept a loss of an arm, a leg, an eye, or even your life? Or, maybe not so bad this time, just a painful broken hand or skinned knuckles! We have mentioned a few of the outcomes of carelessness, but what can be done to change it? First of all, if each and every one of us will practice safety, we can cut down on these so-called accidents. We say so-called, because most of them are caused by unsafe acts of people, as shown in figure 19.

2. So the only answer is to be safe on and off the job; don't take chances. It may take a little longer, but do things the right way, the safe way, and prevent pain and damage.

3. What's in it for the Air Force? The answer is simple—the mission. Every accident, minor or major, hurts the Air Force mission. What happens when you get hurt and go to the hospital? Well, you are still on the payroll; the doctors are on the payroll; time is lost; someone wlse has to do your assigned job, or it has to wait until you return. Results: a lot of extra expense for the Air Force, unnecessary pain for you, and a job not being done! The bad part is that most of this can be prevented.

9. Good Housekeeping

9-1. It has been truly said that "cleanliness is next to Godliness." Good housekeeping is that neatness and cleanliness which prevent fire losses. It is also necessary for the successful performance of a job.

9-2. **Good Housekeeping Principles and Practices.** The first rule of good housekeeping is personal cleanliness. If you are an orderly person and present a good appearance, it will probably be reflected in your work. A person who keeps himself clean has developed a habit which will be carried over into all his actions. Thus, you have made a great stride in the right direction. You are already far ahead of the game in this safety proposition if you have learned to keep yourself and your clothing neat and clean.

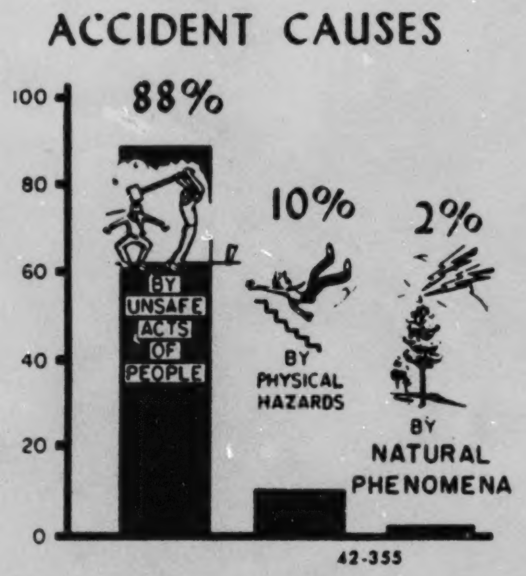

Figure 19. Accident causes.

9-3. Next, there is your work area. Many so-called accidents can be prevented. Much of the lost time and pain could be avoided if you keep your work area clean and orderly. As an example, oil spilled on the floor may cause you or another to slip. The result may be serious injury. If oil or fuel is spilled, it should be covered with an approved compound; or better still, it should be cleaned up immediately. The floor or ramp must be kept free of obstructions. An extension cord or dropped tool may cause you to trip and injure yourself.

9-4. Some units that you will disassemble have small parts. They can easily be lost, broken, or mixed with other parts. To avoid lost time while you hunt another part, keep your work area neat and orderly. A cluttered bench makes effective work almost impossible. This is the starting place for an accident. Worn out parts should be disposed of promptly in the correct places—not on the floor.

9-5. Other items that always find their way into your work area are soft drink bottles. They should be kept in the break area and in the proper container. A broken bottle is one of the most dangerous of objects. Candy and gum wrappers belong around candy and gum—or in a wastebasket. Never allow gum to be found on the floor. It makes for a soiled floor when you step into it, and it might cause a fall.

9-6. Every shop has a designated place for toolboxes when they are not in use. Keep them in their place and keep the lid closed. It does not require much time or effort to open the box when you need a tool, and you may prevent someone from badly bruising his shin. Most shops will have a tool board to make special tools available to all who may need them. Keep them in place. Since some of these tools are quite heavy, get help or use a chain hoist if necessary to put them in place.

9-7. If your shop maintains a stockroom, goods should be stacked neatly, in the prescribed location. This will prevent possible damage to the stored items and also make them readily available.

9-8. Good ventilation leads to good work. Ventilation is actually necessary for the health and safety of personnel. You will find that your work output will drop off considerably if you are too hot or too cold. If the air is dusty or fumes are present, inform your supervisor or trainer. Make him aware of the conditions under which you are working. He can then take the necessary corrective action.

9-9. Proper lighting is another requisite for doing work. Definite standards have been set up by the Air Force to provide the correct illumination for all installations. Good lighting works hand in hand with good housekeeping to eliminate many accident hazards.

9-10. **Fire Prevention.** Closely allied with good housekeeping and absolutely necessary, is a fire prevention system. The best cure for any fire is to prevent its occurrence.You must carry out all safety precautions with regard to the prevention of fires. This means you must know what to do and how to do it when a fire does occur.

9-11. Many fires are caused by carelessness and by poor housekeeping. Oily rags thrown in a corner are excellent material for a healthy fire. Poor storage practices, especially of flammable materials, have caused many avoidable fires. Overloaded electrical outlets coupled with defective circuit breakers may also cause a fire. NO SMOKING signs were made to be observed; lighted cigarettes or matches thrown in wastepaper baskets full of paper are not usually put out by the fall. Here are a few precautions that you should observe with regard to fire prevention:

a. Do not allow large quantities of rags to accumulate. Be sure that all oil rags are kept in approved, closed containers.

b. Observe the signs in the NO SMOKING areas.

c. Never allow your clothing to become saturated with fuel or oil. If they should become that way accidentally, change your clothing as soon as possible. Contaminated clothing may cause skin problems as well as be a fire hazard.

d. Do not permit combustible fluids to be stored in open containers. An example is gasoline or jet fuel.

e. Always make sure that the static lines are in place. The aircraft must be grounded properly before you work on it.

f. Never deposit cigarettes or matches in a wastebasket even if they appear to be out.

g. Be careful with hydraulic fluid; it is not a highly flammable liquid, but it will burn.

h. Use only approved cleaning solvents.

9-12. Fires will occur, no matter how many precautions are taken. You must be ready to fight them quickly and effectively. This implies that you should know the telephone number of the base fire department; and the location of the fire extinguishers. You should also know which type of extinguisher to use for the type of fire you are fighting.

9-13. The telephone number for the base fire department is usually posted in large letters. These posters are at intervals in the shop, in the barracks, and on the flight line. Usually the telephone directory has the number on the cover or first page in large print. Also a gum label with the number is attached to the phone. If alarm boxes are installed on your base, learn where they are and how to use them.

9-14. Fire extinguishers may look alike, but a fire may be made worse if the wrong type of extinguisher is used. Figure 20 will give you a good idea of what types of fires the various extinguishers can be used on. The chart also gives their effective ranges. Study it carefully. When you practice safety, you protect yourself. Our next subject broadly covers the field of safety.

10. Safety Practices

10-1. Each person assigned to the shop should make an effort to improve safety conditions. Always be on the alert for unsatisfactory conditions that could result in injury to personnel or damage to equipment.

Type of Extinguisher	Pump-Tank	Soda Acid	Foam Types	Carbon Dioxide	Chloro-bromomethane
Use on:	Type A Fires: Wood, trash, paper, waste.	Type A Fires: Wood, trash, paper, waste.	Type B Fires: Gasoline, oil and oil base material, varnishes, etc.	Type C Fires: Electrical fires, confined fires on oil, ordinary combustibles.	Type C Fires: Electrical fires.
May also be used on:	--------	--------	Wood, trash, paper, waste.	Type A and B fires.	Small fires.
Method of using:	Direct stream at base of flames.	Work close for penetration. Direct stream at base of flames.	Apply complete blanket of foam over surface. Avoid a direct stream on oil surfaces.	Apply so that gas floods material in a wave-working with draft. Extinguisher lasts only a few seconds.	Direct stream on base of fire or hot surface.
Effective range:	--------	30 to 40 feet	30 to 40 feet	3 to 6 feet	15 to 30 feet
Principle of extinguishment:	--------	Cools burning surfaces below ignition point. Any stream generated tends to smother flames. Practically no gas leaves nozzle.	Blankets burning material with froth or foam, which excludes oxygen. Cools and insulates surface from heat. Blanket prevents flashbacks.	Flame is smothered by heavy blanket of nonflammable gas.	Upon contact with flame or hot surface, the liquid converts into a heavy smothering vapor.
Warning:	Never use on charged electrical equipment, varnish, oils or other fuels. Protect from freezing.	Never use on charged electrical equipment, varnish, oils or other fuels. Protect from freezing.	Never use on charged electrical equipment. Protect from freezing.	CO_2 will not support life. Avoid extended exposure in area where it has been used, especially in pits.	Do not use in closed areas. If liquid comes into contact with skin or eyes, wash immediately with water followed by medical treatment.

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Figure 20. Use of fire extinguishers.

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Preventive maintenance and periodic inspections of shop equipment are important factors in establishing a safe and efficient shop. Undoubtedly, one of the greatest factors in safety is the elimination of the causes of accidents. This depends, in great part, on you.

10-2. Common handtools are a frequent source of injury, and they deserve more respect than they ordinarily receive. A sound rule for the use of handtools is this: Use the tool for its designed purpose and keep it in a good state of repair. Portable power tools are more hazardous than handtools because they are powered by electricity or compressed air. Shops and their equipment present their own particular hazards. An example is a hydraulic component tester with its high pressure. Your supervisor will explain the safety precautions to observe while you operate shop equipment. It's his job to make sure that you don't get hurt. How can he get the work done if his people get hurt? Of course, most supervisors have a personal interest as well as a professional one.

10-3. When working in the shop use the proper guards and observe caution markings found on power equipment. Whenever possible, guards should be permanently installed. Machines with movable guards should have a safety power cutoff switch installed. The colors used for safety markings are *red* to indicate danger or point out emergency stop devices. *Yellow* is used to indicate caution, and *green* to identify safety equipment facilities and their locations. Black and white are used for informational signs.

10-4. **Working Around Danger Areas.** Perhaps we should call danger areas potential danger areas. The danger potential is there, but it normally does not become hazardous unless we become careless. The best way to treat aircraft and aircraft systems is with respect and caution. Don't take chances; know what you are doing.

10-5. Jet aircraft have more danger areas than the reciprocating type; thus, we will base our discussion on jets. For example, when a jet engine is in operation, the turbine wheel, exhaust blast, and the suction effect in front of the engine are danger areas. Each requires particular attention by all personnel working in the immediate area. Other hazards include high-intensity sound, radiofrequency radiation, armed aircraft, egress systems, and power-actuated equipment.

10-6. *Turbine wheel danger areas.* A red stripe painted on the fuselage or engine nacelles indicates where the turbine wheel is. Do not stand in line with that stripe during engine runup. This is a dangerous area.

10-7. *Engine exhaust danger areas.* The high-velocity, high-temperature exhaust blast of a jet engine is especially hazardous to personnel. Do not pass close behind a jet aircraft with its engine operating. The blast distance will vary with different aircraft. For example, F—106 aircraft must be cleared by at least 350 feet behind the airplane.

10-8. *Engine intake danger areas.* The suction effect of a jet engine can also kill a man if he is drawn into the intake. Ordinarily, persons must not approach within 25 feet of jet intakes when the engine is operating. The intake ducts should be free of all objects.

10-9. *High-intensity sound.* While working on aircraft you are exposed to extremely hazardous noise potentials. The noise endangers a person's hearing and interferes with speech communications. It also leads to fatigue. Fatigue leads to faulty maintenance, causing an increase in number of accidents attributed to "maintenance errors." As a result, there is a general increase in the number of accidents.

10-10. The loudness of sound is measured in decibels. Noise levels of 110 to 120 decibels (db) and above are common in the vicinity of operating jet aircraft engines area. Multiengine jets frequently exceed 130 db. You may suffer physical injuries at these higher levels unless you are suitably protected. Noise levels of 85 db and below are considered relatively safe.

10-11. Ear defenders, selection of aircraft runup area, noise-suppression devices, and other precautions protect against noise hazards. The noise intensity of jet aircraft is greatest to the rear of the engines at an angle of 45° on either side. Do not work or stand in these high-intensity noise areas unless absolutely necessary. Ear defenders alone will not give you enough protection at levels of 130 to 140 db. If you must work in these areas wear a headset in addition to earplugs. Then keep the period of exposure as short as possible.

10-12. A person who has worked too long in areas with high db levels will show symptoms of sickness or injury. He may have pain, a feeling of fullness, and a ringing or burning of the ears; dizziness, impairment of mental concentration; and occasionally nausea, vomiting, or weakness of the knees. Emotional irritability is often a sign of noise fatigue. When any of these symptoms are noted, the affected person should be taken from the noise area immediately. A medical officer should examine him before the effects wear off.

10-13. *Radiofrequency radiation.* Specific precautions are necessary for personnel handling fuel and ammunition near high-powered radiofrequency transmitters. There is the potential danger that the radar will be beamed at them. A high-powered radar beam can ignite steel wool 100 feet away.

10-14. If the microwave radiation of a radar beam strikes the human body, it causes internal heating. This may cause damage to the tissue if the rise in temperature is sufficiently high or prolonged. Eye tissue and the testes are more sensitive to these damaging effects than other parts of the body. Shielding and distance give some protection. The best rule to follow is: radar and certain radio equipment must be turned off when maintenance is being performed.

10-15. *Armed aircraft.* Be extra careful when performing maintenance on aircraft that are armed. Armed aircraft have warning signs near the cockpit entrance and on the fire control system panel. They also have safety pins with streamers on the arm devices. Part II of AFTO Form 781 must have a statement indicating what arms are installed. Although only limited maintenance is normally performed on armed aircraft, observe and obey all armament warning signs; be cautious in the use of external power. Do not operate any armament switches or remove their safety devices. Do not remove the streamered safety pins from armament devices. Before you perform maintenance on armed aircraft, study the applicable aircraft technical manuals. Also read other safety directives in order to be completely familiar with the safety precautions.

10-16. *Egress systems.* Maintenance personnel accidentally firing the ejection seat or canopy could result in serious injury and damage to the aircraft. Ejection seat and canopy ground safety pins are installed immediately after flight. They will remain safetied while the aircraft is on the ground. These ground safety pins are attached to red streamers. The streamers have the words REMOVE BEFORE FLIGHT stenciled in large letters on them. The ground safety pins provide protection from accidental firing of the seat and canopy initiators. Usually, for extensive maintenance, egress personnel will disarm the seat and canopy.

10-17. Here is a word of warning concerning initiator safety pins. It is possible to install the initiator safety pin incorrectly by making them look safe when they're ready to blow! Figure 21 illustrates the correct, as well as the incorrect, way of installing safety pins in the initiators. Notice the safety pin in the "unsafe" drawing! The initiator goes part way into the hole but does not seat in the retaining groove of the pinhead.

10-18. When working in the seat or canopy area exercise particular care to avoid accidental arming and firing. Extreme heat or unintentional movement of the actuating mechanisms can fire the ejection seat catapult or canopy remover. Do not place tools in your pockets while working in the cockpit area. Screwdrivers in hip pockets have caused accidental firing of seats. Know the aircraft egress systems that you are working around. Know where the safety pins are installed and how they should be installed. These systems should command the same respect that you have for a machinegun. They are, in a way, types of firearms.

10-19. *Power-actuated surfaces and equipment.* Aircraft with power-operated (most are hydraulic) devices, such as flight control surfaces and landing gear, present a potential danger. If you carelessly operate any of these, you can damage equipment or injure someone. These systems are designed to operate quickly and against heavy airloads. They can be quite dangerous unless all precautions are observed. It is your job to check out and maintain these systems, but use caution. Before going into a bomb bay to work on it, make sure that you have disabled the system. Don't get trapped by someone throwing switches! Curiosity can be dangerous and there is a little bit of it in everyone. "What will happen when I flip this switch?" Watch out for the hangar pilot! When operating systems to check them out, make sure that they are clear of personnel and equipment. Have someone stand by and make sure that everyone stays clear of the danger areas.

10-20. *Sharp edges.* The control surfaces of some jet aircraft have unusually sharp edges. When working on or near these edges be especially cautious. During prolonged maintenance periods, use suitable protective covers on such edges. If you cannot do this, tape the sharp edges. Attach red streamers to indicate the danger area Watch where you are going; serious injuries have occurred from persons simply walking into sharp edges of flight controls.

10-21. *Aircraft walkways and NO-STEP areas.* The aerodynamic efficiency of aircraft can be affected by damage from maintenance personnel walking on aircraft surfaces. When repair work makes it necessary to walk or step on the aircraft, use the designated walkways. Under no circumstances walk or step on areas designated as NO-STEP areas. Besides causing damage, you can very easily slip and fall when stepping on slick wing surfaces. Designated walkways are covered with nonskid material. High-speed aircraft must have smooth surfaces; for this reason, you have to be extra careful when climbing onto or walking on external surfaces other than nonskid areas. Wear either

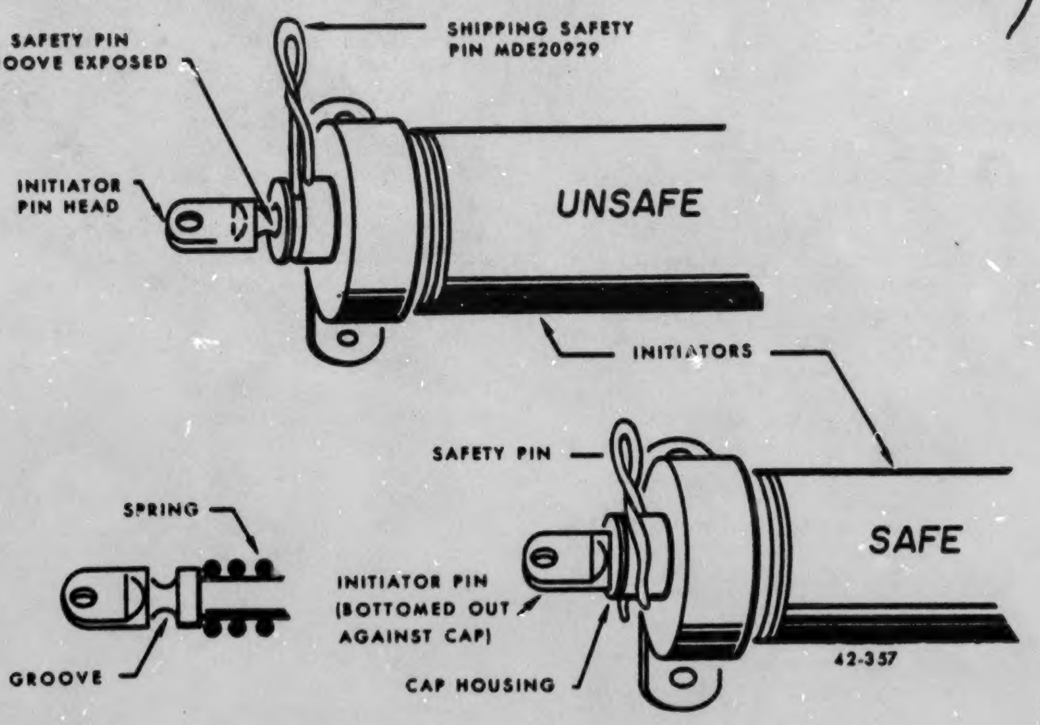

SAFETY PIN GROOVE EXPOSED
SHIPPING SAFETY PIN MDE20929
INITIATOR PIN HEAD
UNSAFE
INITIATORS
SAFETY PIN
SPRING
SAFE
INITIATOR PIN (BOTTOMED OUT AGAINST CAP)
GROOVE
CAP HOUSING
42-357

Figure 21. Safe/unsafe initiators.

suitable soft-soled shoes or protective pads, and be careful not to walk on NO-STEP areas.

10-22. *Hydraulic servicing precautions.* Servicing aircraft hydraulic systems is not as hazardous as servicing fuel or oxygen systems. But. hydraulic fluids under high pressures do involve certain dangers and require precautions on your part. Make certain that all pressure is removed from the system before you disconnect any lines. Furthermore, you cannot properly service most aircraft with pressure in the system. If fluid is to be added to a pressurized hydraulic reservoir, the reservoir must be depressurized slowly. Then remove the filler cap. Since different aircraft have different hydraulic systems, the servicing procedures and precautions also differ. Detailed servicing instructions and precautions are found in the applicable aircraft technical manual. The hydraulic systems of some aircraft are serviced with a hydraulic test stand attached and operating. This involves observing precautions for the test stand as well as the aircraft. Servicing with clean hydraulic fluid of the correct type is extremely important in order to prevent failure of the system. Remove any hydraulic fluid spilled in or on the aircraft, and wipe the area clean. Be careful not to spill hydraulic fluid on other components such as electrical or electronic units.

10-23. It is necessary to service accumulators with dry, filtered air or nitrogen to the correct pressure. Never service a hydraulic accumulator with high-pressure oxygen. Oxygen itself is not flammable, but it will support combustion in other flammable materials. If oxygen is permitted to mix with flammable gases or fumes, the result can be highly explosive. Oxygen and grease, oils, or fuel make a highly dangerous combination; keep them apart.

10-24. When using high-pressure air, be extremely careful and tolerate no horseplay; it can be very dangerous. Air pressure strong enough to clean dust or dirt is also strong enough to blow it up into a person's eyes and ears, and cause possible damage to the body. Pressures as low as 10 to 15 psi have been known to cause serious injuries. It has been estimated that pressure of only 4 psi will rupture the intestines when "goosing" is indulged in.

10-25. *Radioactivity.* You may in the future be required to work around radioactive material. You must be aware of the safety precautions to be observed and instantly recognize the radiation warnings. We have prepared a general list of precautions that must be observed. Remember, you cannot see radioactivity, and it may be hours before you feel the effects of radiation.

a. You must have a physical examination if you are exposed to radiation. If you are working around radiation you will be scheduled for an examination periodically.

b. Be sure that the base monitor briefs you on the measures and hazards involved.

c. You must wear protective clothing while working around radioactive materials.

d. Wear a film badge or a pocket dosimeter at all times when around radioactivity.

e. Practice good hygiene such as washing your hands and face thoroughly before eating or smoking.

f. Do not eat, drink, smoke, or chew gum while in the area.

g. Report any scratch or cut made by a radioactive material. Such scratches may cause severe sores and be very slow in healing.

h. Do not wear personally owned items such as watches and rings. They may become contaminated.

i. Do not handle telephones, reports, or other similar objects while wearing protective gloves. You may contaminate them.

j. Do not breathe dust or metallic particles which come from radioactive materials.

10-26. To aid in the identification of radioactive material, the AFTO 9 series forms have been devised. These are yellow with a magenta (reddish-purple) warning symbol. A description of the forms and instructions for handling contaminated items are contained in the 00–110 series Technical Orders. Any time these warning symbols appear, precautions must be taken. The AFTO 9 series form are listed as follows:

a. AFTO Form 9, Radiation Area Warning Placard (8 1/2 x 11 inches).

b. AFTO Form 9A, Radiation Warning Tab.

c. AFTO Form 9B, Radioactive Material Warning Label (2 1/4 x 3 5/8 inches).

d. AFTO Form 9C, Radioactive Material Warning Placard (8 1/2 x 11 inches), shown in figure 22.

e. AFTO Form 9D, Radiation Ingestion Hazard Placard (8 1/2 x 11 inches).

f. AFTO Form 9E, High Radiation Area Warning Placard (18 x 24 inches). This placard will be used to identify an area where radiation intensity is 100 milliroentgens per hour or greater.

10-27. Do not enter a radiation area unless it is absolutely necessary. When you must work in a radiation area, follow all precautions and do not stay any longer than necessary.

10-28. **Off-Duty Safety.** A man assigned to a hazardous operation as part of his daily duty is conscious of danger. He will prepare himself accordingly. He is also under almost constant supervision during duty hours. He knows that if he violates regulations and directives he will be reprimanded or disciplined for his wrong doing. Thus, he is kept in line.

10-29. Now follow this same airman after hours. He showers, relaxes, and looks around for some recreation. His carefulness usually relaxes right along with his body. Perhaps he decides to go to the hobby shop, engage in some sport, or go for a drive. For these activities, there is no safety officer to caution him; many times, there are no posters to warn him and no supervisor to admonish him. He's strictly on his own, often without the ability to handle the assignment. Let's take a look at some of the hazards that might confront this airman. Also, what he should do to meet them. We shall focus on safe driving during off-duty hours, safety in sports, safe conduct in the barracks, and safety in hobby shop activities.

10-30. *Safety in driving.* As a source of off-duty pleasure, the automobile rates top billing with Air Force personnel. Unfortunately, it is also their greatest threat to life and limb. For example, in 1960, private motor vehicles driven by Air Force personnel were responsible for more than 340 deaths and 3,200 disabling injuries.

10-31. What can you do to reduce the off-base, off-duty accident rate? First of all, learn the traffic laws. Secondly, observe these laws strictly. Several factors must be considered regarding the exact observance of traffic laws, among them the following:

a. Never try to travel too far in too short a period of time. This can be assured by your adhering to your base's travel policies.

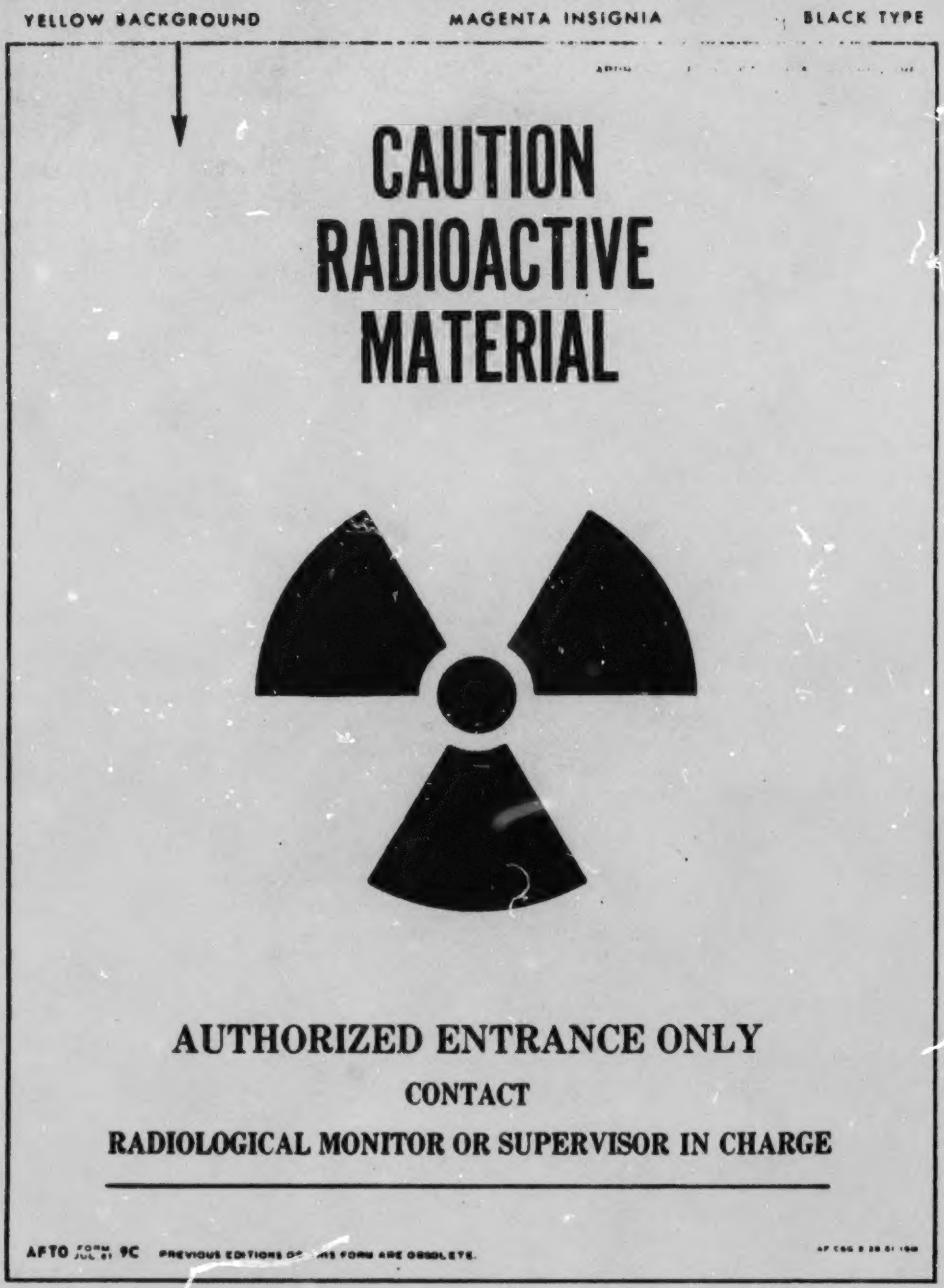
b. Don't continue driving when you are sleepy or overtired. Remember that when you have an accident you endanger not only yourself but the driver and passengers of other vehicles as well.

c. Make sure your car is in good mechanical condition before starting on a trip. Malfunctioning brakes, lights, and windshield wipers, as well as badly worn tires, invite auto accidents.

d. Remember—alcohol and driving do not mix.

e. Speed limits are made to be observed and highways are not intended to be racetracks.

10-32. You can undoubtedly add many more precautions to the ones listed. If you want to go


YELLOW BACKGROUND
MAGENTA INSIGNIA
BLACK TYPE

CAUTION
RADIOACTIVE
MATERIAL

AUTHORIZED ENTRANCE ONLY
CONTACT
RADIOLOGICAL MONITOR OR SUPERVISOR IN CHARGE

AFTO FORM JUL 61 9C PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

53-3

Figure 22. Radioactive material warning.

on living with a whole and sound body, drive carefully.

10-33. *Safety in sports.* Sports should occupy a very important place in your Air Force life. Military planners are becoming more and more conscious of this fact. This is a means for helping personnel do their jobs better and develop themselves physically. The more common athletic activities are swimming, football, boxing, wrestling, basketball, baseball, track, and golf. There are activities sponsored by the Air Force after duty hours. When properly organized and supervised these activities do much to train the airman physically and mentally. However, when engaged in improperly, they become a source of danger and often a cause of injury.

10-34. *Safety in barracks.* At first glance, barracks life seems to be perfectly harmless. However, the very fact that so many different types of men live in one building presents the danger. The barracks can be a source of a great many accidents which are not always accidental.

10-35. Horseplay should never be tolerated in the barracks. During morning cleanups and G.I. parties, serious injuries can be—and often are—caused by happy-go-lucky broom and mop wielders who exhibit their prowess as fencing experts rather than cleaners.

10-36. Smoking in bed is a practice that leads to many unpleasant results. Butt cans and not the center aisle of the bay should be used to dispose of cigarette butts. In case of a fire in the barracks, use the same procedure outlined in a preceding section of this chapter where fire prevention was discussed.

10-37. *Safety in the hobby shop.* The base hobby shop—and most modern bases have one—is a good place to relax after a day's work and yet do something useful and practical with your spare time. Most hobby shops are built and equipped on the assumption that the using personnel are not fully skilled in what they are doing. Even so, you must still exercise care in using the equipment provided.

10-38. Carpentry equipment is especially dangerous. Such tools as motor-driven saws, power drills, and other wood-shaping equipment should be used with caution and according to directions. Failure to do so can result in irreparable bodily injuries. Following are a few precautions of which every hobby shop user should take note:

a. Make sure you are checked out on the use of equipment.

b. Use safety guards at all times.

c. Make sure the floor around machines is free from stumbling and tripping hazards.

d. Keep the floor clean of sawdust and scraps.

10-39. Never forget that hobby shop SOPs were written for your protection. It is to your advantage to become completely familiar with all operating procedures before attempting to use any piece of hobby shop equipment.

10-40. **Accident Reporting.** If you are involved in an accident, your supervisor and the ground safety officer are required to fill out forms reporting the circumstances and the extent of damage and injuries sustained. Although there are several forms, the USAF Form 711 and 711a, Ground Accident/Incident Report, is the one that will most concern you. Your supervisor has to know his business in order to fill out the form, and your cooperation is necessary. Accidents are reported as prescribed by AFR 127–4. Reportable accidents are:

a. Injuries to Air Force military and civilian personnel or those stationed, assigned, or employed at Air Force installations.

b. Injuries to non-Air Force personnel resulting from Air Force ground operations.

c. Accidents and incidents resulting in disabling injuries or property damage of $25 or more. Such accidents are referred to as "reportable ground accidents." When an accident is reported for any of the foregoing reasons, all injuries without regard to their extent or amount will be included.

10-41. Remember, safety is a full-time job. Safety, then, is my job, your job, everbody's job. Observance of the rules set down can easily mean the difference between the complete success or utter failure of the mission of your organization. Safety also requires self-discipline and proper supervision and training. Supervision and training are essential parts of any maintenance organization and will be discussed in a later volume.

17

Hydraulic Fluids and Plumbing Materials

PROPER OPERATION and correct maintenance of hydraulic systems depend on the use of the correct fluid. As a pneudraulic repairman, you should be able to identify the various types of fluids used in hydraulic systems. Serious damage can result if the wrong fluid is used. The cleanliness of hydraulic fluid is also a critical factor in our newer aircraft.

2. Various plumbing materials make up a hydraulic system. For example, there are seals, backup rings, fittings, tubing, and hose. You must be familiar with these various seals and backup rings, because they are designed for specific systems. No hydraulic system will operate satisfactorily unless its tubing and hose can withstand the pressures under which the system operates.

3. Safetying devices can also be considered as plumbing materials. These devices are designed for specific uses, and the correct safety device must be used and applied in the correct manner.

4. Let's first discuss fluids that are used with hydraulic systems. Then we'll follow this with the various plumbing devices.

11. Fluids

11-1. There are several types of fluids used in hydraulic equipment. They are referred to as "hydraulic fluids" and "cleaning agents." During our discussion of fluids, we will also cover flushing and servicing of hydraulic systems.

11-2. **Hydraulic Fluids.** Hydraulic fluids are generally classified by their type and base. For example, there is the petroleum-base fluid, the vegetable-base fluid, and the synthetic-base fluid.

11-3. *Petroleum-base fluid.* One petroleum-base fluid is specified by MIL–H–5606. Petroleum-base fluid (5606) is dyed red for easy identification. It is generally supplied in 1-quart and 1-gallon containers and is available in one grade only. This one grade has an operating range of –65°. (–53.9° C.) to 275° F. (135° C.) The advantage of this wide operating range is the ability of the fluid to perform adequately in summer and winter temperatures. The seals required with the petroleum-base fluid may be of synthetic rubber, leather, or metal composition. This type of fluid is used in most aircraft and missile hydraulic systems. Automatic pilots and control surface mechanisms also use this type of fluid.

11-4. Another petroleum-base fluid is presently known as MIL–H–6083. Fluid 6083 is supplied in only one grade. It is intended for use as a preservative oil in shock struts, hydraulic equipment, and spare parts. It is also used as a testing and flushing oil for some hydraulic components. It may also be used as an all-temperature operating fluid in independently serviced shock struts. However, it should not be used in regular aircraft hydraulic systems.

11-5. *Vegetable-base fluid.* This is a blue colored fluid and is now *obsolete* for normal Air Force use.

11-6. Flush all systems and components inadvertently serviced with fluid of the incorrect type. Should an aircraft hydraulic system or component accidentally be serviced with the incorrect fluid, it must be immediately drained. Check the proper technical order for detailed instruction.

11-7. To determine the fluid used in an aircraft, check the maintenance instruction technical order. Another method is to read the instruction plate on the individual unit or reservoir.

11-8. Whenever fluid is drained from an aircraft hydraulic system or component, it must not be reused. Instead, it must be disposed of according to Air Force regulations.

11-9. Synthetic fluids were developed to counter heat problems in some new aircraft. The close tolerances of some units require a fluid to withstand abnormal temperatures. The heat can come from the speed of the aircraft or internal design of the units.

11-10. The fluid used in these systems is a synthetic-base and carries a MIL–H–8446 specification number. MIL–H–8446 can be distinguished from other hydraulic fluids by its golden-amber color. The temperature operating range is approximately –67° F. (–55° C.) to approximately 350° F. (177° C.). The maximum sustained operating temperature is 270° F. (132° C.).

11-11. The disadvantage of MIL–H–8446 is its susceptibility to moisture contamination. Moisture causes a chemical change in the fluid, which in turn causes sludge and varnish deposits to form. This, of course, is an undesirable factor. To help in keeping MIL–H–8446 moisture-free, it is supplied in specially designed containers. They are pressurized with a dry nitrogen charge.

11-12. Seals used with MIL–H–8446 are not interchangeable with seals used with any other type of hydraulic fluid. These seals can be distinguished by a white dash, and 90° from it, a yellow dot. When replacing seals make certain that they are properly packaged and labeled when you receive them.

11-13. Remember, MIL–H–8446 is not a general-purpose fluid. Be sure to follow the technical order for servicing and other maintenance performed on aircraft using this fluid.

11-14. **Servicing Hydraulic Systems and Components for Storage.** Before a complete aircraft hydraulic system can be placed in storage, it must be properly serviced. The servicing procedure depends on the type of fluid used for normal operation. If the system contains petroleum-base fluid, drain and inspect a sample of fluid from the lowest point in the system. The sample must be free of sludge and dirt. If it is, add a sufficient quantity of fluid to bring the reservoir level to its normal height. Should the sample show signs of foreign matter of any kind, the complete system must be drained. Then flush the system with fluid (5606) and refill with fresh petroleum-base fluid.

11-15. When units are prepared for storage or shipment, the procedure also depends on the type of fluid normally used. A unit using the petroleum-base fluid must be flushed internally with oil. The unit is then drained to the drip point, and all ports are plugged. No cleaning or flushing is necessary when returning the unit to service.

11-16. **Cleaning Agents.** A hydraulic unit, when disassembled and overhauled, should always be cleaned with a suitable solvent. Solvents remove dirt, grit, foreign matter, or sludge that may be lodged on the internal parts. Grit or dirt, for instance, decreases the sealing ability of a metal-to-metal contact. Rubber seals may be scratched or scarred, or possibly a valve may be held slightly open by foreign matter. Therefore, thorough cleaning of a unit is very important.

11-17. When overhauling a unit, always check the applicable technical order. The technical order will give the correct procedure for disassembling, cleaning, assembling, and testing. If no particular type of solvent is specified, PS–661 may be used. PS–661 is normally used on units which require petroleum-base fluid for operation. Denatured alcohol is an approved solvent for units operating with vegetable-base fluid. Trichloroethylene is the recommended cleaning agent for units used with MIL–H–8446 fluid. Whichever type is used, be sure to clean the unit and internal parts according to the technical order instructions. Before assembling, be sure that all parts are completely dry. Compressed air or a lint-free cloth may be used for drying.

11-18. Since some of the solvents used are very flammable and volatile (forms vapor rapidly), exercise extreme care when using them. Keep the cleaners in a tightly sealed container. If used indoors, be sure that the work area is well ventilated.

11-19. **Fluid Contamination.** Contamination in a hydraulic system is the presence of any material other than the specified hydraulic fluid. This includes water, metal, dust, and other solids. We will discuss contamination effects, control, prevention, and the two general sources of contamination internal and external.

11-20. *Internal contamination.* This can be caused by normal wear of the pump or other components. When filters are used too long (especially paper element type), particles may begin breaking off the filter element. Moving seals and backup rings also add contamination to the system.

11-21. *External contamination.* This is generally caused by poor maintenance practices. Some examples are leaving hydraulic lines open after removing a part; wiping fittings with dirty rags; leaving valves, tubing, etc., uncovered on workbenches; changing fluid with dirty equipment; and installing new or rebuilt parts that have not been properly cleaned.

11-22. *Effects of contamination.* There are many effects of contamination. We will use one example for our discussion. During final landing approach, the pilot was unable to get the landing gear down. He was forced to use the emergency extension system, with which he was able to slowly lower the gear. Investigation revealed a small metal particle in the gear selector valve which kept the valve in the UP position. This kept hydraulic pressure on the gear-up side of the actuators. Fortunately, the emergency-down system worked. It applies pressure to the large side of the actuating cylinder piston, this overcoming the up-pressure. The contaminant in this case was determined to have been left in the valve during assembly.

11-23. *Control and prevention on contamination.* To help control contamination, a kit has been developed to sample and check fluid for contamination. When the fluid shows excessive contamination, the system will have to be drained and flushed. Always follow the tech orders written for your type aircraft.

11-24. The following list contains a few general rules which will aid in the prevention of contamination:

a. Cap or plug all open connections when removing a part.

b. Don't use dirty rags to wipe off connections.

c. Clean and deburr new tubing and fittings before installing them.

d. Store new or overhauled parts in sealed containers.

e. Before installing a pump, fill it with hydraulic fluid.

f. After a pump failure, flush the system thoroughly.

g. Give test stands and ground equipment the same care you give the aircraft.

h. Don't abuse hydraulic flexible hoses. They introduce contaminants from their walls when kinked or run over or when quick-disconnects are not cleaned before joining.

11-25. *Flushing contaminated hydraulic systems.* Hydraulic systems should be flushed

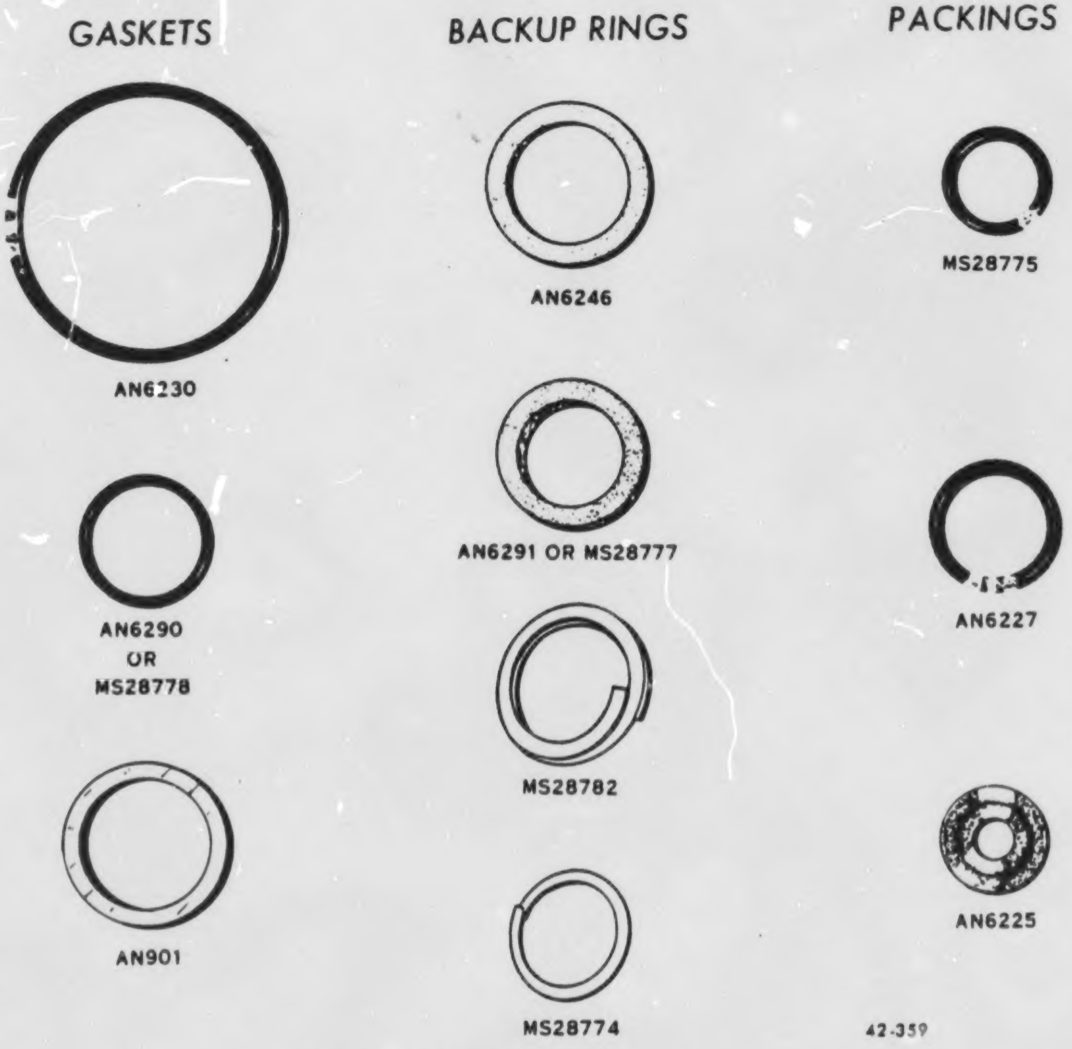


Figure 23. Packings, gaskets, and backup rings.

Seal Dimensions				Back-Up Rings		
Inside Diameter	Width	Spec No.	Spec No.	Teflon Single Spiral Spec No.	Teflon Double Spiral Spec No.	Leather Solid Ring Spec No.
3/8	1/16	AN 6227B-7	MS 28775-012	MS 28774-12	MS 28782-7	AN 6246-7
3/8	3/32	AN 6227B-8	MS 28775-110	MS 28774-110	MS 28782-8	AN 6246-8
7/16	3/32	AN 6227B-9	MS 28775-111	MS 28774-111	MS 28782-9	AN 6246-9
4 3/8	1/8	AN 6230B-23	MS 28775-245*	MS 28774-245	MS 28783-23	AN 6244-23
4 3/8	3/16	AN 6227B-51	MS 28775-348	MS 28774-348	MS 28782-51	AN 6246-51
4 1/2	1/8	AN 6230B-24	MS 28775-246*	MS 28774-246	MS 28783-24	AN 6244-24
4 1/2	3/16	AN 6227B-52	MS 28775-349	MS 28774-349	MS 28782-52	AN 6246-52
4 1/2	1/4	AN 6227B-88	MS 28775-425	MS 28774-425		AN 6246-88
4 5/8	1/8	AN 6230B-25	MS 28775-247*	MS 28774-247	MS 28783-25	AN 6244-25
4 5/8	1/4	AN 6227B-53	MS 28775-426	MS 28774-426	MS 28782-53	AN 6246-53

*To be used as a static seal only.

42-428

Figure 24. Seal comparison chart.

whenever contaminants are present. The flushing procedure varies somewhat for different types of aircraft. Listed below are general procedures:

a. Drain the system reservoirs and discard the fluid.

b. Clean or replace all filter elements in the aircraft and in the test stand.

c. Service the aircraft with the test stand and then cycle all the subsystems. This allows the filters to remove contaminants from the fluid.

d. After repeated cycling, recheck all filter elements for cleanliness. If a system is severely contaminated, it may be necessary to repeat the above steps several times. It may even be necessary to remove the components from the aircraft for complete disassembly.

11-26. From the preceding discussion, you can readily see that keeping fluid clean is of major importance. However, there are other factors of equal importance; for example, the proper use and installation of seals, backup rings, fittings tubing, hose, and safetying devices. This is absolutely necessary for the system to operate at its maximum efficiency. Let's continue our discussion, then, by starting with seals and backup rings.

12. Seals and Backup Rings

12-1. Seals used in hydraulic and pneumatic systems are of two general classes: packings and gaskets. Packings are used to provide a seal between two moving parts of a unit. The gasket is used as a seal between two stationary parts.

12-2. Seals are made from several different types of materials. The material depends on the use of the seal and the type of fluid it will contact. Leather, synthetic rubber, natural rubber, and metal are the materials used. Synthetic rubber and leather seals are designed for use with petroleum-base fluids. Natural rubber seals are used with vegetable-base fluid, and metal seals may be used with either type.

12-3. The shape of a seal is its major distinguishing feature. Standard seals (and backup rings), with their corresponding AN (Air Force-Navy) and MS (Military Standard) numbers, are shown in figure 23. As a pneudraulic repairman, you should become familiar with corresponding seal and numbers. In some cases, for example, hydraulic leaks were a direct result of using the wrong seal or backup ring. The mechanic did not know the differences. Figure 24 will help you compare some of the various seals and backup rings used in hydraulic and pneumatic systems. This chart should not be used for ordering seals or performing maintenance on aircraft. It is provided to show the differences in the various seals. Conditions will arise, however, when a nonstandard seal will be determined by its specific use and location. Figure 25 illustrates a few of the nonstandard seals.

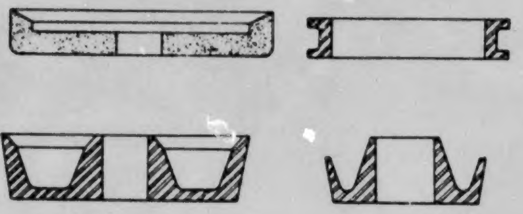


Figure 25. Special shape seals.

12-4. If necessary, seals are manufactured specifically for a particular aircraft. For example, the B—58 aircraft hydraulic system used seals of this type. These part numbers were listed in the applicable illustrated parts breakdown (IPB).

12-5. **Part Numbers.** Standard seal part numbers are also found in the applicable IPB. If you can't find a part number in the IPB, the next step is to measure the seal. The seals size may help you determine the part number. Figure 26 shows the various dimensions that are required. At least two of the three dimensions of the O-ring seal must be measured. If two are known, the third can easily be determined. For example, the outside diameter (O.D.) can be found if the width and inside diameter (I.D.) are known. Twice the width plus the I.D. will equal the O.D. When ordering a seal from supply, give the standard AN part number. For example, the part number of a particular packing is AN 6227, followed by a dash number. This dash number can be any number from —1 to —88; notice in figure 24 that a —88 comes between the —52 and —53, depending on the size of the seal. To determine the correct dash number, convert the dimensions of the seal on the specification listing. Dimensions for packings, gaskets, and backup rings are also listed in their particular specification. The V-ring, shown in the lower portion of figure 26, will be discussed later.

12-6. **Color Coding.** A color code on the O-ring seal identifies the type of system it is used in and, generally, the manufacturer. O-rings have either a series of colored dots arranged clockwise or a colored stripe around the outer circumference. The first dot (reading in a clockwise direction) or the stripe, indicates the system in which the o-ring is used. The following color codes are used: Red indicates use in fuel systems only; blue indicates use in hydraulic and pneumatic systems; and yellow indicates use in oil systems only. NOTE: A white

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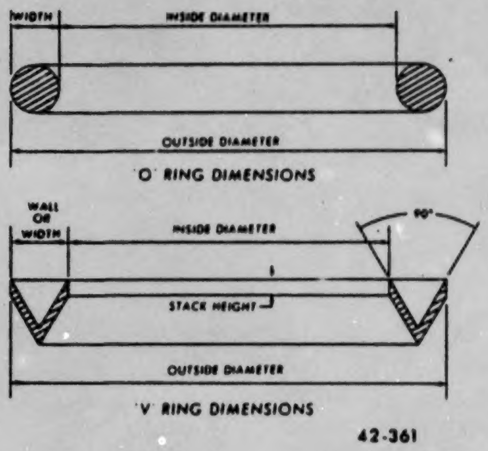

Figure 26. O-ring and V-ring dimensions.

dot appearing first indicates a nonstandard seal. The second dot then indicates the system.

12-7. **Description of Commonly Used Seals and Backup Rings.** Refer again to figure 23 for our discussion on seals and gaskets. Gaskets will be discussed first, and then followed by backup rings and packings.

12-8. *Gaskets.* Starting in the upper left-hand corner we have the AN6230 gasket. This gasket will always have a 1/8-inch width. Its smallest I.D. is 1 5/8 inches. This would be an AN6230—1 gasket. An important point to remember when ordering AN6230 (or AN6227) seals is to substitute a "B" for the *dash.* For example, the above part number would be AN6230B1. (The "B" denotes that this is the latest AN Standard.) AN6230 gaskets are coded with a series of colored dots arranged clockwise. The first dot is blue, indicating use in hydraulic and pneumatic systems. The other dots indicate the manufacturer. AN6230 gaskets are used only as a static seal, as illustrated in figure 27.

12-9. The next gasket (shown below the AN6230) is the AN6290 or MS28778. This gasket is a compression type seal used on (AN or MS) connection fittings. Figure 27 illustrates the use of a MS28778 or AN6290. (MS28778 is gradually replacing AN6290.) The blue stripe around the outer circumference of the seal indicates use in hydraulic and pneumatic systems. The width of this seal varies from 0.064 to 0.118. These dash numbers are the same as the corresponding fitting size.

12-10. Another standard gasket is the AN901 made of soft aluminum. It is commonly called a crush (universal) washer. Referring to figure 23, you will see the gasket in the lower left-hand corner. It is used with a universal elbow, as illustrated in figure 27. Note that two gaskets are required for this type of installation. The dash number is also in accordance with the size fittings with which it is to be used. There are no markings on the AN901 universal washer.

12-11. We have discussed some of the standared gaskets. There are other types of gaskets made of synthetic rubber or cork which are used where pressures are low.

12-12 *Backup rings.* Still referring to figure 23, you will find several backup rings in the center row. These backup rings are used as a nonextrusion device. The top backup ring (AN6246) is made of leather and is used with AN6227 packings. Looking at figure 23, you can see that this ring is not as thick as the AN6291 backup ring. Leather backup rings are dyed yellow, blue, or black on the hair (or grain) side. Another backup ring, the AN6244 (not shown), is similar to the AN6246 except for size. The AN6244 backup ring is used with the AN6230 gasket generally when pressure is 1500 psi or higher. This backup ring is easy to identify because its dash number is the same as the corresponding gasket's (AN6230) dash number. Thus, we have the same approximate dimensions.

12-13. The next backup ring shown is the AN6291. This backup ring is also similar to the AN6246 and AN6244. Its major difference is its thickness, which is almost double that of the

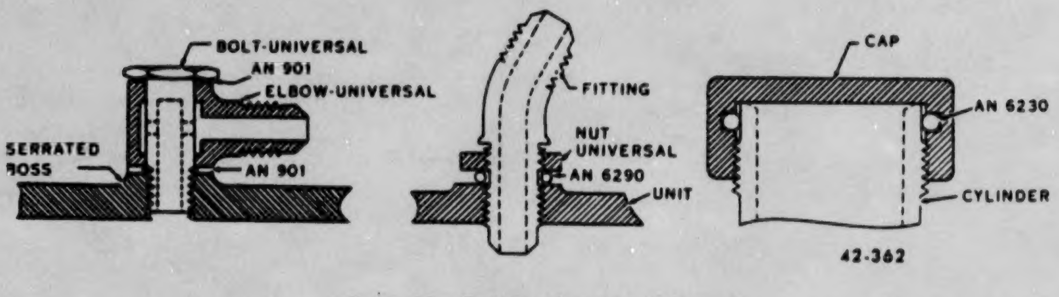

Figure 27. Typical gasket installation.

30

others. Another backup ring, the MS28777 (not shown) is gradually replacing the AN6291. MS28777 backup rings are also made of leather.

12-14. The MS28782 is a Teflon backup ring and is used with AN6227 and MS28775 packings. Looking at the MS28782 in figure 23, you will notice that it is in the shape of a coil. Each end of the turn comes to a semisharp edge. When installing, make sure this edge is on the outside. The color of Teflon backups is milky white.

12-15. Another Teflon backup ring (not shown) is MS28783. This backup ring is similar to MS28782 except for size. The MS28783 backup ring is used with the AN6230 or the MS28775 gaskets.

12-16. The MS28774 shown at the bottom of the middle row in figure 23 is another Teflon backup ring. This packing backup ring is used with MS28775 O-ring packings. Notice that this ring has a single turn only.

12-17. *Packings*. Now, let's discuss the packings shown in the right-hand row of figure 23. The top number (MS28775) covers gaskets and packings.

12-18. The MS28775 seal has an operating range of −65° F. to 275° F. It should be used only where the technical order specifies; otherwise some leakage at −65° can be expected. This seal can be identified by a single blue dot. MS28775 seals in sizes 0.239-inch I.D. or smaller do not require color-dot identification. The MS28775 seals supersede the MS28784 seals that had a blue dot 180° away from the other dots.

12-19. The next O-ring packing shown is the AN6227. This packing is identified by a blue dot plus the manufacturer's dot code. This O-ring packing has an operating temperature range of −65° F. to 160° F.

12-20. The packing shown in the lower right-hand corner of figure 23 is the AN6225 V-ring. This ring can be identified by its V-shape. The V-rings also have their part number formed on the inside of the V. V-rings are made of leather or synthetic rubber. Figure 26 shows that the dimensions required for V-rings are the same as those for O-rings. Also required is the stack height. This stack height is not required for ordering from supply. It is used only when determining how many V-rings to install in a set.

12-21. Another packing (not shown) that is used in some aircraft struts is the D-ring. It is referred to as a D-ring because its cross section is in the general shape of a D. This seal is larger in thickness because backup rings are not required with its use. O-ring packings installed in struts on large aircraft have a tendency to roll when compressed rapidly. This, in turn, tends to cut the seal. D-rings eliminate this problem and provide a better seal.

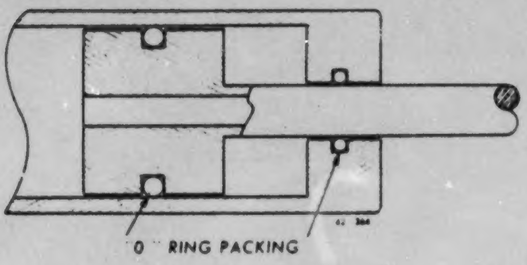

Figure 28. Typical O-ring installation.

12-22. **Installation of Seals and Backup Rings.** Generally, the O-ring seal requires no adjustment when it is installed. Figure 28 shows a typical O-ring installation. However, you must observe a few precautions at installation, or early failure will result. First of all, check to see that the seal is the right size. Inspect it visually for cuts, nicks, or flaws, and discard it if any defects are noted. Technical orders will specify what special lubricant is applied. When installing, use extreme care to prevent scratching or cutting the seal on threads or sharp corners. Also, make certain that it is not installed twisted; otherwise, it will not function correctly. To facilitate removing an O-ring seal, a special tool may be made, as shown in figure 29. This tool can be made of soft iron, aluminum, or brass rod. Be sure that the edges are flattened and free of burs. Some seals may be removed by squeezing the seal between the thumb and forefinger, forcing the O-ring out of the groove. Then the entire seal is removed.

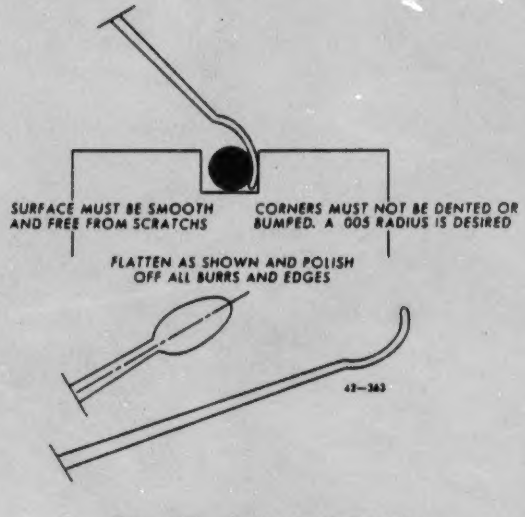
SURFACE MUST BE SMOOTH AND FREE FROM SCRATCHS
CORNERS MUST NOT BE DENTED OR BUMPED. A .005 RADIUS IS DESIRED
FLATTEN AS SHOWN AND POLISH OFF ALL BURRS AND EDGES

Figure 29. O-ring removal tool.

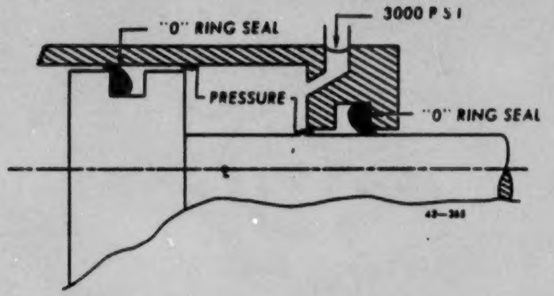
"O" RING SEAL
3000 P S I
PRESSURE
"O" RING SEAL
℄

Figure 30. O-ring seals, "pinched" condition.

12-23. The O-ring seal, when used alone, is limited to systems having a maximum operating pressure of 1500 psi or less. This is particularly true when it is used as a "running" seal. In the event the seal is subjected to high pressure (3000 psi), it may become pinched. Figure 30 shows a set of O-ring seals being pinched because of the high pressure. This condition may be prevented by using backup rings. The older types of backup rings are made of leather. In some cases, however, the leather backup rings caused severe corrosion. Leather coming in contact with moisture causes a chemical reaction which starts the corrosion. Thus, you will find that Teflon backup rings are replacing many of the leather ones. Even so, leather backup rings are still being used, and for that reason we will discuss their use.

12-24. The hair or outer side of the leather backup ring is called the grain side. The cut or inside of the leather is called the flesh side. The hair side will also be dyed yellow, blue, or black.

12-25. Proper installation of backup rings may be seen in figure 31. The flesh side of the backup ring is always next to the gland. This will position the grain side next to the O-ring seal. If pressure is exerted on the seal in one direction only, you place the backup ring away from the pressure. If pressure applied in alternate directions, one backup ring must be placed on each side of the O-ring seal (see fig. 31).

12-26. A V-ring packing will provide a seal in only one direction. If a piston is to move in two directions under fluid pressure, two sets of V-rings must be used. Figure 32 shows a typical V-ring installation in which one set (A) prevents fluid leakage around the piston rod; another set (B) acts as a seal when pressure is moving the piston to the left; and a third set (C) seals when the piston is moving to the right.

12-27. Installation of the V-ring seals is slightly different from that of O-ring seals. The rings are placed in their respective grooves, one at a time. Make sure that they are seated properly; then, tighten the adjusting nut. The

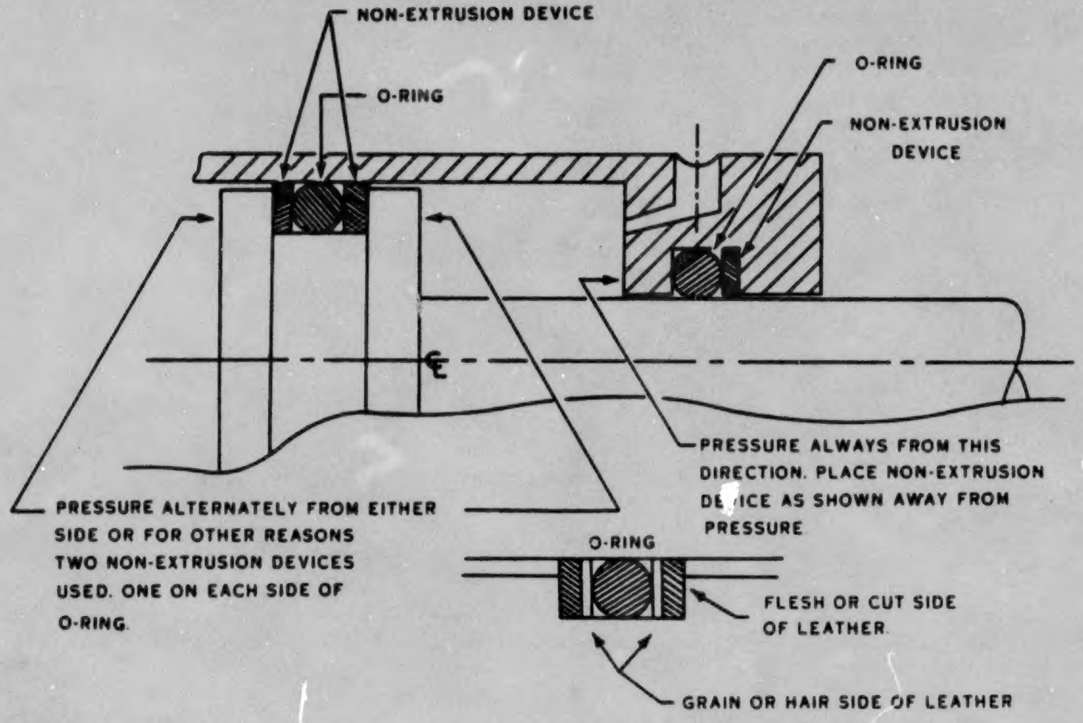
NON-EXTRUSION DEVICE
O-RING
O-RING
NON-EXTRUSION DEVICE
℄
PRESSURE ALWAYS FROM THIS DIRECTION. PLACE NON-EXTRUSION DEVICE AS SHOWN AWAY FROM PRESSURE
PRESSURE ALTERNATELY FROM EITHER SIDE OR FOR OTHER REASONS TWO NON-EXTRUSION DEVICES USED. ONE ON EACH SIDE OF O-RING
O-RING
FLESH OR CUT SIDE OF LEATHER
GRAIN OR HAIR SIDE OF LEATHER

Figure 31. O-ring with nonextrusion devices.

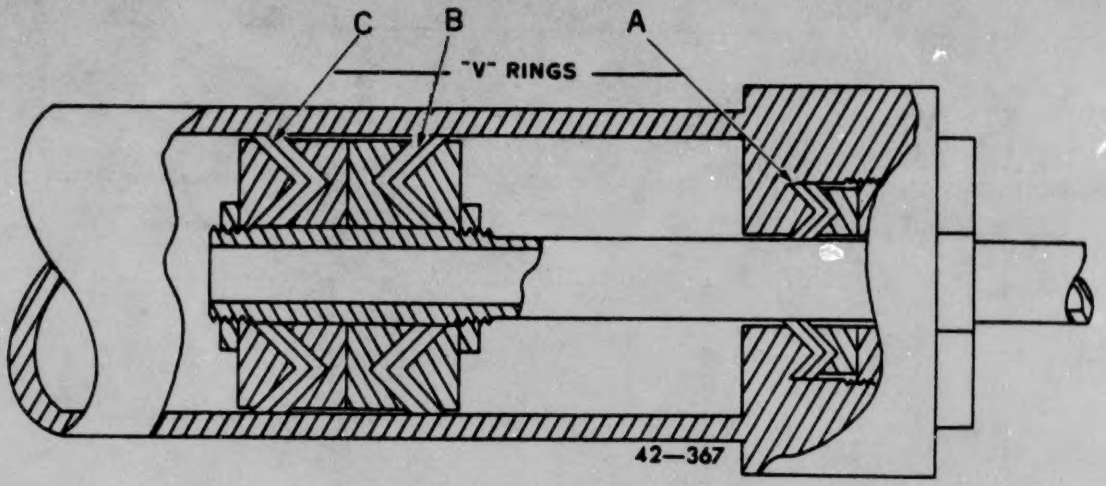

Figure 32. Typical V-ring installation.

adjustment nut should be tightened enough to hold the seals securely. If possible, the unit should be operated by hand to check adjustments.

12-28. Before you install leather V-rings and backup rings, they should be made pliable. Do this by soaking them in hydraulic fluid. All the other seals and backup rings should be lubricated with the applicable fluid prior to installation.

12-29. When using packings and gaskets in pneumatic systems, lubricate the O-ring and groove with pneumatic grease, Specification MIL–L–4343. The seals must be thoroughly lubricated at all times to function properly. Lack of lubrication will increase friction enough to cause jamming and rapid wear or tearing of running seals.

12-30. Packings and gaskets should be stored in a dark, cool, dry place; they should be kept away from excessive heat, exposure to strong air currents, dampness, and dirt. Do not expose them to electric motors or other equipment that gives off heat and ozone. Any packing or gasket should not remain in storage for a period of more than 5 years.

12-31. Figure 33 shows application of "O-rings, gaskets, and back up rings." Study this figure. It will reinforce what you have learned in this section on the identification and use of these items.

12-32. This completes our discussion of seals and backup rings. Next, let's discuss the fittings used to interconnect hydraulic systems. Then we can use the fluid and seals already discussed.

13. Fittings

13-1. Whenever tubing is connected to other tubing, to flexible hose, or to any unit, a fitting is used. All late model aircraft are equipped with the AN- or the MS-type fitting. However, older aircraft may still have the old AAF811 (AC, Air Corps) fitting installed on some tubing. Incidently, sizes 2, 3, 4, 5, 28, and 32 AAF811 fittings are interchangeable with the corresponding AN fitting. The main differences between the AN and AAF fittings can readily be seen in figure 34.

13-2. AN fittings are identified by their color, which may be either blue or black. Blue indicates that the fitting is made of aluminum alloy, and black designates steel. The letters AN are usually stamped somewhere on the fitting.

13-3. A fitting, depending on its type and use, will have either pipe threads or machine threads. Pipe threads, similar to those used in ordinary plumbing, are tapered. When two pipe fittings are joined, a male into a female, their threads form a seal. When pipe thread fittings are used, an antiseize compound (JAN–A–669) should be used to prevent seizing and high-pressure leakage. Machine threads (straight threads), similar to those used on nuts and bolts, form no seal. This type of thread is used only to draw connections together. A flare, crush washer, or a synthetic seal is used to make the connection fluidtight. Machine threads have no taper. Figure 34 illustrates machine threads.

13-4. **AN Fittings.** Figure 35 shows the most commonly used AN fittings that connect to the component. Tees, unions, adapters, elbows, etc., commonly known as connectors, are self-explanatory. However, the terms "universal" and "bulkhead" need a little more explanation. "Universal" means that the fitting can be set at

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NUMBER	NAME	APPLICATION	SYSTEM	PUBLICATION GOVERNING		IDENTIFICATION	PROCUREMENT SPECIFICATION	QUALIFIED PRODUCTS LIST	REMARKS
				DESIGN INSTALLATION	STORAGE AND USE				
	O-RING								
AN6227	Packing, O-ring	Static and dynamic	Hyd, pneu	MIL-P-5514	ANA Bul 438 T.O. 42E2-1-2	Colored dots	MIL-P-5516	QPL-5516	General use -65° F to +160° F
AN6230	Gasket, O-ring	Static only	Hyd, pneu	MIL-P-5514	ANA Bul 438 T.O. 42E2-1-2	Colored dots	MIL-P-5516	QPL-5516	General use -65° F to +160° F
AN123851 through AN123950	Seal, O-ring	Static and dynamic	Hyd, pneu	MIL-P-5514	ANA Bul 438	White stripe on ring	AMS-7274	---	Primary use-recip engines and propellers
MS28772	Packing, O-ring	Landing gear shock strut as rod seal only	Hyd	MIL-P-5514	ANA Bul 438	Colored dots	MIL-P-5516	QPL-5516	---
MS28775	Packing, O-ring	Static and dynamic	Hyd (MIL-H-5606), pneu	MIL-P-5514	ANA Bul 438 T.O. 42E2-1-2	Blue dot	MIL-P-25732	QPL-25732	General use -65° F to +275° F
MS29561	Packing, O-ring	Static and dynamic	Hyd, syn lubricant, pneu	---	ANA Bul 438	---	MIL-P-7362	QPL-7362	---
	O-RINGS FOR FLARED TUBE FITTINGS								
MS28778	Packing, flared tube	Flared tube bosses	Hyd, pneu	AND-10064	---	Blue stripe around circ of ring	MIL-G-5510	QPL-5510	Replaces AN6290
	NONEXTRUSION RINGS								
MS9058	Ring	Teflon backup for use with MS28778 O-ring gaskets in flared tube bosses	All	AND-10064	---	---	AMS-3651	---	---
MS28774	Retainer, single turn	Teflon backup for use with AN6227, AN 6230, MS28775, and MS29561	All	MIL-P-5514	---	---	MIL-R-8791	None	---
MS28777	Ring	Leather backup for use with flared tube bosses	All	AND-10064	---	Dyed different colors	MIL-R-5521	QPL-5521	Replaces AN6291
MS28782	Retainer	Teflon backup for use with AN6227 and MS28775	All	MIL-P-5514	---	---	MIL-R-8791	None	In process of replacing AN6246
MS28783	Ring	Teflon backup for use with AN6230 and MS28775	All	MIL-P-5514	---	---	MIL-R-8791	None	Replaces AN6244
MS35803	Retainer	Leather backup	All	---	---	---	---	---	---

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Figure 33. Application of O-ring, gaskets, and backup rings.

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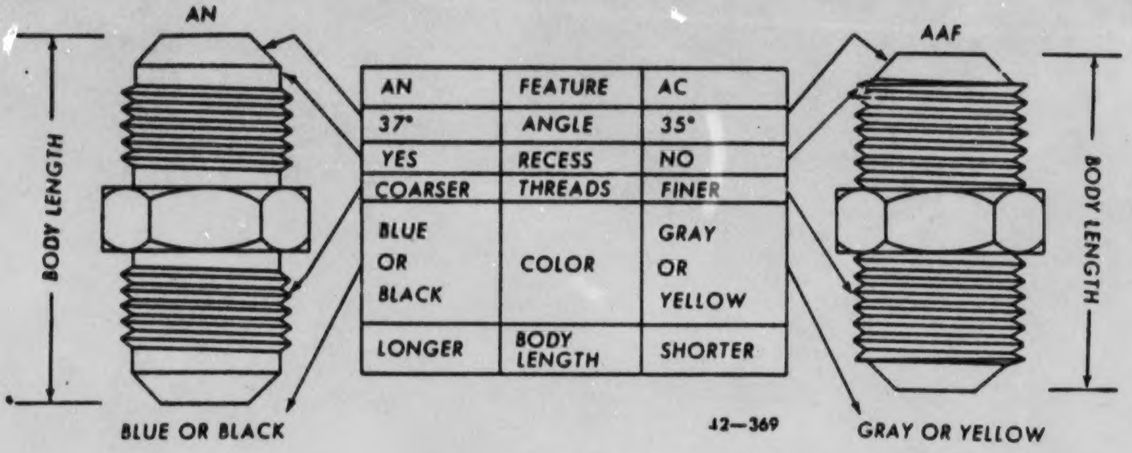

AN
AAF
BODY LENGTH
BODY LENGTH
BLUE OR BLACK
GRAY OR YELLOW
42—369

AN	FEATURE	AC
37°	ANGLE	35°
YES	RECESS	NO
COARSER	THREADS	FINER
BLUE OR BLACK	COLOR	GRAY OR YELLOW
LONGER	BODY LENGTH	SHORTER

Figure 34. AN and AAF fitting differences.

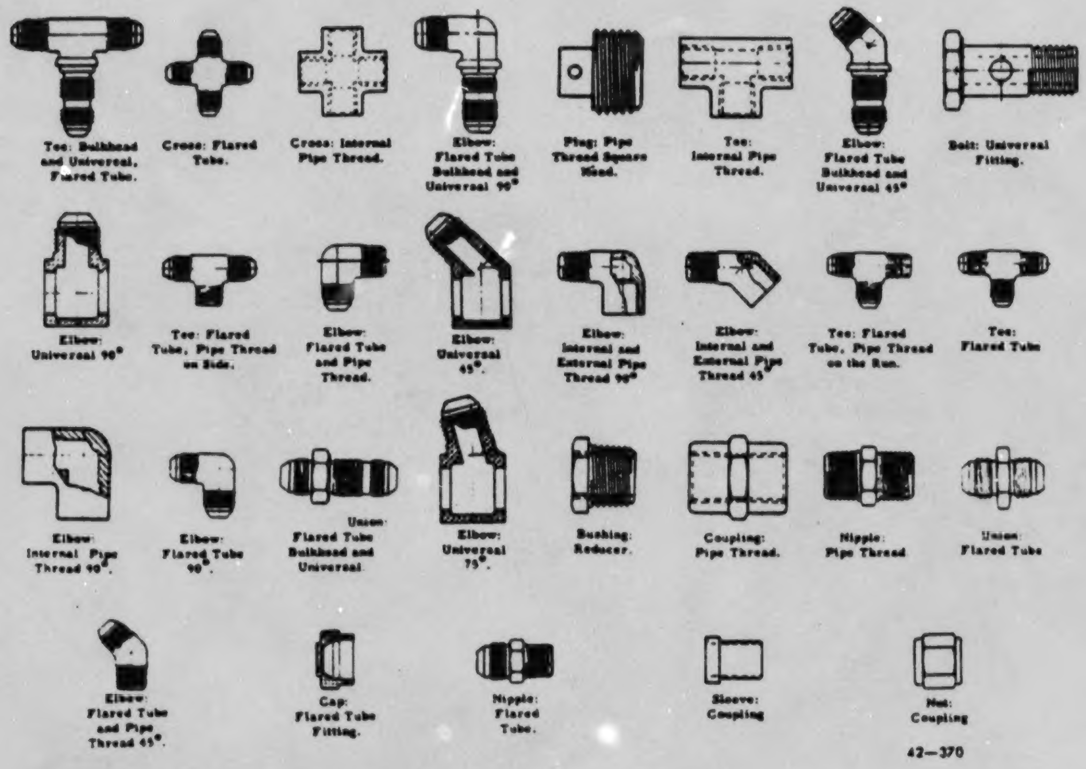

Tee: Bulkhead and Universal, Flared Tube.
Cross: Flared Tube.
Cross: Internal Pipe Thread.
Elbow: Flared Tube Bulkhead and Universal 90°
Plug: Pipe Thread Square Head.
Tee: Internal Pipe Thread.
Elbow: Flared Tube Bulkhead and Universal 45°
Bolt: Universal Fitting.
Elbow: Universal 90°
Tee: Flared Tube, Pipe Thread on Side.
Elbow: Flared Tube and Pipe Thread.
Elbow: Universal 45°.
Elbow: Internal and External Pipe Thread 90°
Elbow: Internal and External Pipe Thread 45°
Tee: Flared Tube, Pipe Thread on the Run.
Tee: Flared Tube
Elbow: Internal Pipe Thread 90°.
Elbow: Flared Tube 90°.
Union: Flared Tube Bulkhead and Universal.
Elbow: Universal 75°.
Bushing: Reducer.
Coupling: Pipe Thread.
Nipple: Pipe Thread
Union: Flared Tube
Elbow: Flared Tube and Pipe Thread 45°.
Cap: Flared Tube Fitting.
Nipple: Flared Tube.
Sleeve: Coupling
Nut: Coupling
42—370

Figure 35. AN fittings.

any angle. The "bulkhead" denotes that it is long enough to pass through a bulkhead. Thus, this type of fitting can be mounted solidly to a bulkhead or unit with one outlet adjusted to any angle.

13-5. The AN flare fitting is shown in figure 35. It consists of an AN818 coupling nut (shown in the lower right-hand corner of fig. 35), an AN819 or MS20819 sleeve (shown left of the nut), plus the connector (any flared tube fitting shown in fig. 35).

13-6. **MS Fittings.** MS flareless fittings are designed primarily for high-pressure (3000 psi) hydraulic systems. They may be subjected to severe vibration or fluctuating pressure. These types of fittings are also three-piece units. However, unlike AN fittings, MS fittings are

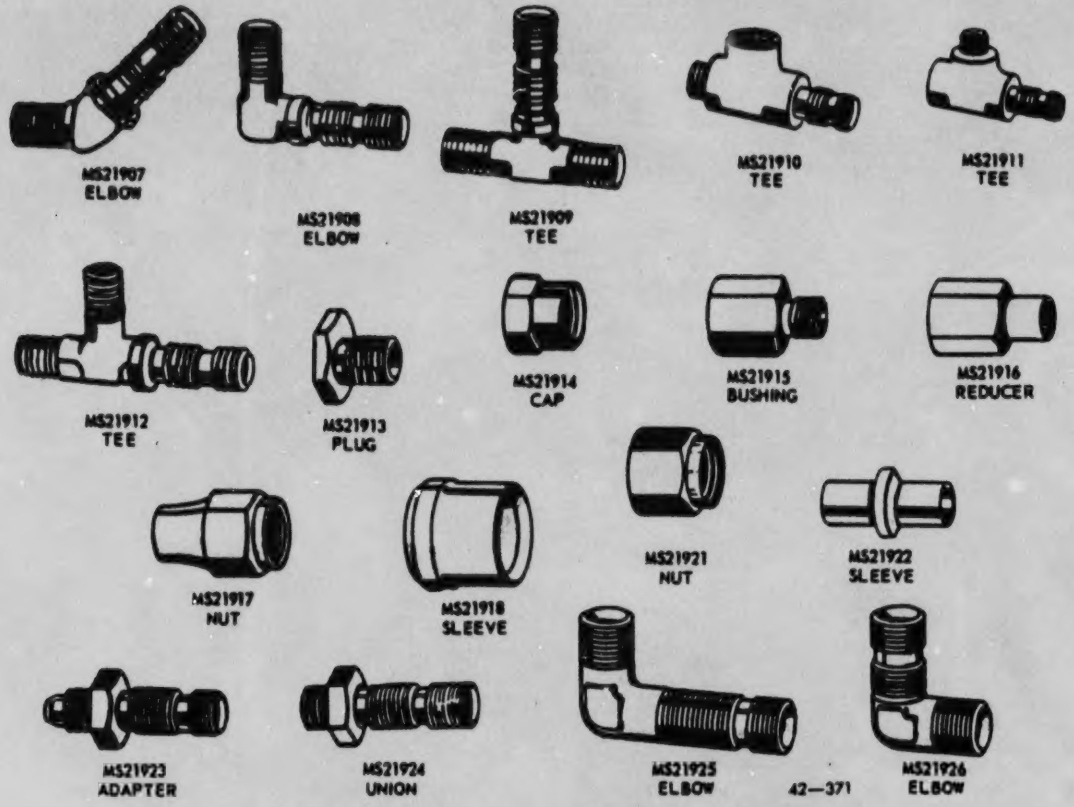

MS21907
ELBOW
MS21908
ELBOW
MS21909
TEE
MS21910
TEE
MS21911
TEE
MS21912
TEE
MS21913
PLUG
MS21914
CAP
MS21915
BUSHING
MS21916
REDUCER
MS21917
NUT
MS21918
SLEEVE
MS21921
NUT
MS21922
SLEEVE
MS21923
ADAPTER
MS21924
UNION
MS21925
ELBOW
42—371
MS21926
ELBOW

Figure 36. MS fittings.

flareless. Some aircraft use the flareless fittings in hydraulic and pneumatic systems. Their use is limited to fittings up to size 16 (1 inch). Above 1 inch, AN fittings are used. Systems using tubing larger than 1 inch would most likely be low pressure.

13-7. MS flareless fittings use two types of nuts and sleeves. The older type is the MS21917 nut and the MS21918 sleeve, as shown in figure 36. The newer type, MS21921 nut and MS21922 sleeve, are shown to the right of the older type. Figure 36 also shows some of the common MS connectors.

13-8. The MS flareless fittings have the same straight thread as do standard AN flared fittings. Hence, they will mate with existing AN internal threads in valves and other equipment. MS flareless fittings made of aluminum are colored yellow, green, or brown. Steel MS flareless fittings are silver colored (natural cadmium-plated).

13-9. Notice in figure 37 that the connector consists of an externally threaded port with an internal cone seat. It has a straight counterbored section at the base of the cone seat which holds the tube. Notice also that there is a reverse angle tubing seat at the base of the straight counterbored section. This angle is 45° in aluminum connectors and 15° in steel connectors. The purpose of this angled seat is to prevent excessive inward collapse of thin-walled tubing when the fitting is tightened. Figure 38 shows that the base of the internal thread in the nut has a 45° bevel. This will push against the sleeve during assembly. This tends to compress the length of the sleeve. This motion produces two effects. First, the compression forces the sleeve cutting edge into the

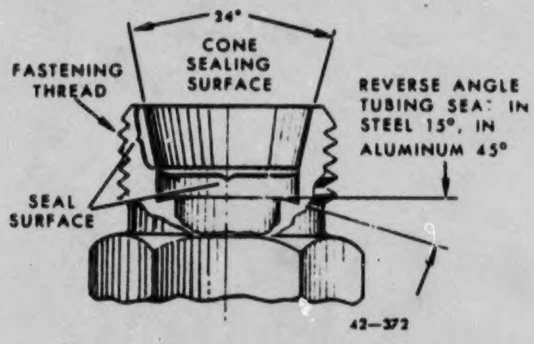

24°
CONE
SEALING
SURFACE
FASTENING
THREAD
REVERSE ANGLE
TUBING SEAT IN
STEEL 15°, IN
ALUMINUM 45°
SEAL
SURFACE
42—372

Figure 37. MS flareless connector.

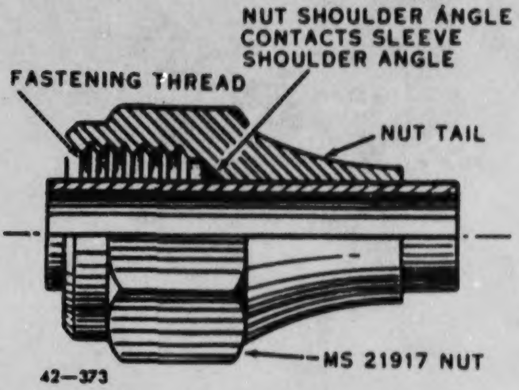


Figure 38. One type of flareless MS nut.

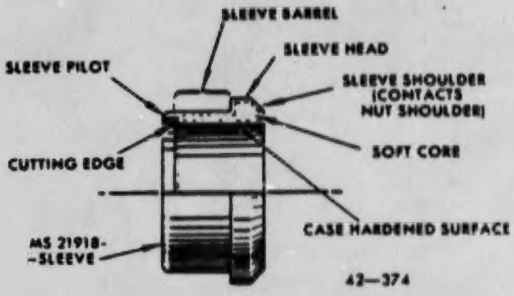


Figure 39. One type of flareless MS sleeve.

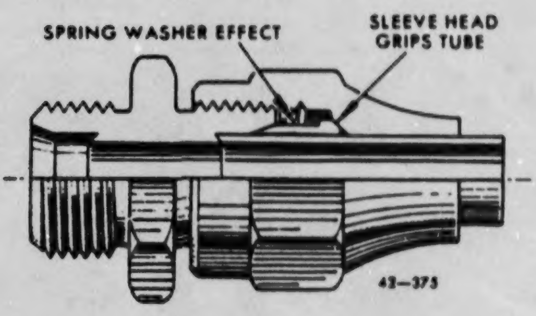


Figure 40. MS flareless connector with sleeve and nut showing installed condition.

tube (see figure 39). Secondly, it causes the head of the sleeve to grip the tubing. This second action tends to reduce the transmission of stresses to the sleeve cut. These stresses, caused by vibration, would cause failure of the tubing at the sleeve cut. The sleeve (shown in fig. 39) has a head, barrel, pilot, and cutting edge. During assembly (presetting), the cutting edge is forced inward. This is done by the cone-shaped seat in the nut as the sleeve is driven forward by the nut. The pilot guides the cutting edge and limits the depth of cut. The difference between the sleeve head angle and the nut angle compresses the sleeve against the tubing. The sleeve becomes bowed as a result of the compression force applied by the nut. Figure 40 shows a sleeve's spring washer effect (bowed) when installed. This prevents loosening of the nut when severe vibration is encountered.

13-10. The method of making up part numbers for MS flareless fittings is the same as for AN flared tube fittings. A number is added to the basic part number to indicate the O.D. of the tube in sixteenths of an inch. The letter D placed after the basic part number denotes aluminum alloy. As an example, MS21917D10 would be the part number of an aluminum flareless nut used with 5/8-inch (10/16-inch) tubing. The 10 at the end of the number dentoes 10/16 inch. Flareless sleeves and caps are furnished in steel only.

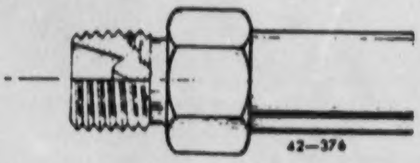


Figure 41. Presetting tool.

13-11. **Presetting Flareless Fitting Tube Assemblies.** When assembling flareless fittings, you select the proper size presetting tool (shown in fig. 41). Clamp the tool in a vise on a workbench. Then slide a nut and a sleeve onto the tubing. Make certain that the pilot and cutting edge of the sleeve point toward the end of the tube. Using the proper lubricant (system fluid), lubricate the threads of the tool and nut, the pilot of the sleeve, and the seat of the tool. Hold the tube ends firmly against the bottom of the seat of the tool. Then slowly screw the nut onto the tool. Do this until the cutting edge of the sleeve grips the tubing sufficiently to prevent rotation of the tube. Then tighten the nut an additional 1 1/6 turns for all sizes regardless of the tubing material used. This tightening will seat the sleeve cutting edge in the outer surface of the tubing. When presetting the fittings on thin-walled tubing (less than 0.022-inch aluminum and 0.018-inch steel), a mandrel should be used for support to prevent its collapsing.

13-12. Now remove the presetting tool. Clean off all excess lubricant from the fitting and components. Make sure that no foreign particles remain that could possibly be carried into the system. A preset tubing assembly may be installed and removed many times without damage. That is, if the technical order procedures are strictly adhered to.

13-13. **Installing Tube Assemblies.** Before installing a tube assembly in an aircraft, you should inspect the tubing and connectors carefully. Yor can make minor repairs to a tube assembly if you follow technical order procedures. The repairs consists of removing scratches or smudges caused during presetting. The tube assembly should be clean and free from all foreign material.

13-14. *AN tube assemblies.* Before installing an AN tube assembly, check for dents, scratches, and any foreign material. When installing, be sure the tube assembly is properly aligned prior to tightening; never pull it into place with the nut! If the tube assembly is misaligned, it becomes prestressed and may leak during operation of the system. Start the coupling (B) nuts on each end of the tubing by hand. Then tighten them to the proper torque. If the B nut does not turn easily by hand, apply a little hydraulic fluid on the external threads. Do not use thread compound—flared tube fittings form a metal-to-metal seal.

13-15. Applying the proper torque to the B nut is very important. Overtightening may badly damage or completely cut off the tube flare. Also it may ruin the sleeve or the B nut. Failure to tighten sufficiently can be equally serious. This condition may allow the lines to leak under system pressure. Proper torque prevents overtightening or undertightening of the B nut. A B nut should never be tightened when there is pressure in the line. The pressure could damage the flare and also cause an incorrect torque to be applied.

13-16. *MS flareless tube assemblies.* Procedures for installing the MS flareless tubing are as follows. The tube centerline should be in line with the centerline of the connector. It should not have to be forced into position. If the tube is too long it may be filed to fit. Be sure to remove all filings. Now tighten the nut with your fingers until a sharp rise in torque is noted. From this point apply from 1/6 to 1/3 turn, which is from one to two hex flats on the nut.

13-17. As with AN fittings, it is important that the nut on MS fittings be tightened properly. Overtightening a leaking MS flareless fitting, for example, will deform the sleeve or tube and cause additional leaks. Never exceed 1/3 turn! Also, do not use thread compound on MS fittings.

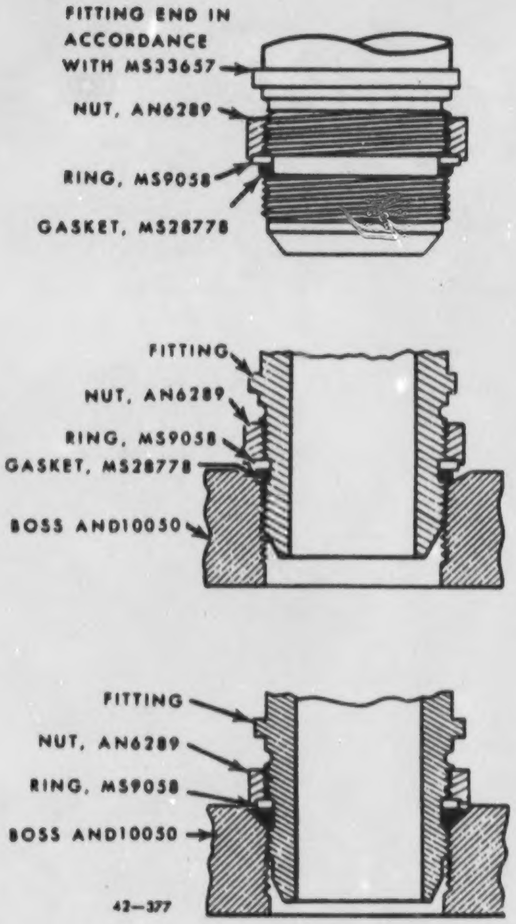


Figure 42. Universal fitting installation of AN or MS fittings.

13-18. *Universal fittings.* In many cases leaks may have developed because of improper installation of universal fittings (AN or MS flareless). This improper installation causes the gasket to be cut by the threads. The nut (AN6289) might be stripped because of insufficient thread grip when torqued to the proper value. The proper method of installing universal fittings is shown in figure 42. It is necessary to use the proper (AN6291 or MS9058) backup ring. The Teflon backup rings (MS9058) are used in lieu of the leather backup rings where temperatures exceed 160° F.

13-19. The first step in the installation procedure is to coat the male threads. Next, work the ring into the recess in the nut and install the gasket. Turn the nut down until the gasket is pushed firmly against the lower threaded section of the fitting. This is illustrated in the upper portion of figure 42. Now, install the fitting into the boss (AND10050). But, keep the nut turning *with the fitting* until the gasket contacts the boss. This point can be determined by a sudden increase in torque, as shown in the middle of figure 42. With the fitting in this position, put a wrench on the nut to prevent its turning. Then turn the fitting in 1 1/2 turns. Now, position the fitting (if it is an elbow or tee) by turning it in not more than one additional turn. Finally, hold the fitting and turn the nut down tightly against the boss to the required torque. There must be no extrusion of the ring. In the lower portion of figure 42, the gasket is in the proper position to prevent leakage.

13-20. **Repairing Pneudraulic Tubing.** Pneudraulic tubing is repaired by replacing with similar material. Damage such as nicking and scratching of tubing can be minimized by using care. Most damage of this kind occurs from careless handling of tools during maintenance of the aircraft. Any dent less than 20 percent of the tubing diameter is not objectionable unless it is on the heel of a bend. A nick no deeper than 15 percent of the wall thickness may be reworked by burnishing—provided it is not on the heel of a bend. When pressures are in excess of 100 psi, tubing with nicks in excess of 15 percent of the wall thickness should be rejected.

13-21. Since hose is used for the same purpose as tubing, it is the next topic on our agenda. We will first tell you how hose is identified, and then follow this with a discussion of fabrication, installation precautions, inspections, and storage.

14. Pneudraulic Hose

14-1. Pneudraulic hose is used for the same purpose as tubing—to route the fluid to and from the various units. However, hose has one advantage over tubing—flexibility. For example, hydraulic pumps should always have a flexible hose attached to them. The vibration that is set up by an operating pump would ultimately cause rigid tubing to fail.

14-2. Flexible hose assemblies are fabricated by hand or by a production machine. The production machine is covered in a later volume. The principles of hose fabrication are the same regardless of the method used.

14-3. **Hose Identification.** Four types of hoses are generally used for hydraulic and pneumatic systems. These hoses fall into two classes: medium-pressure and high-pressure. For medium-pressure we use two types: rubber hose MIL–H–8794 and Teflon hose MIL–H–27267. The third type is a high-pressure rubber hose MIL–H–8788. These three types may be locally manufactured into hose assemblies. The fourth type of hose used is high-pressure Teflon. It is not authorized for local manufacture at the present time.

14-4. Hose is also designated by a dash number, according to its size. The dash number is stenciled on the side of the hose and indicates the size tubing it is used with. It does not denote the inside or outside diameter of the hose. For example, a hose with a –8 stenciled on it is used with a –8 tubing. The –8 tubing has an outside diameter of 1/2 inch (8/16 = 1/2). The inside diameter of the hose will not be 1/2 inch; it will be slightly smaller, equal to the wall thickness of the tubing. The actual inside diameter of both hose and tubing is the same.

14-5. Hose has other identification markings stenciled on it. As an example, most pneudraulic hose is marked with the specification, the size, the quarter and year of manufacture, and a 5-digit number identifying the manufacturer. Figure 43 shows a hose with these identifying markings. These markings are in yellow-colored letters and numerals which indicate the natural lay (no twist) of the hose. They are repeated at intervals of not more than 9 inches along the length of the hose. The operating range of hose is approximately –65° to 200° F.

14-6. Notice that figure 43 shows the construction of medium-pressure hose (MIL–H–8794). It consists of a synthetic inner tube, impregnated cotton braid, single wire braid, and impregnated cotton braid outer covering, which has a rough finish. Figure 44

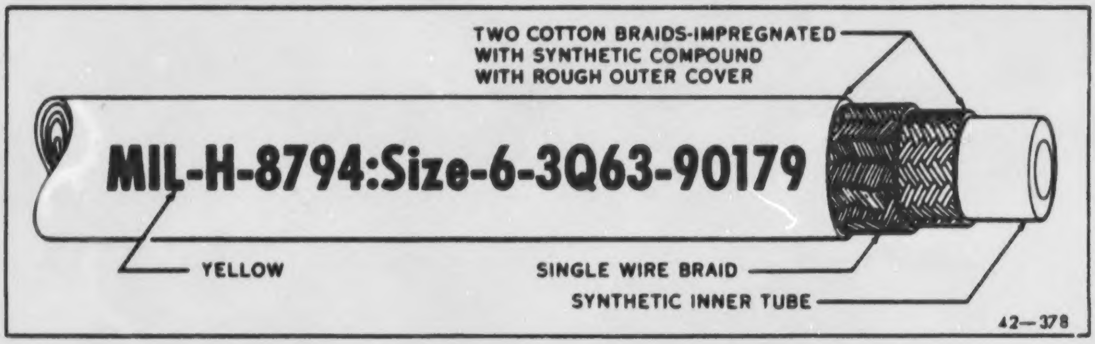


Figure 43. MIL-H-8794 medium-pressure hose construction.

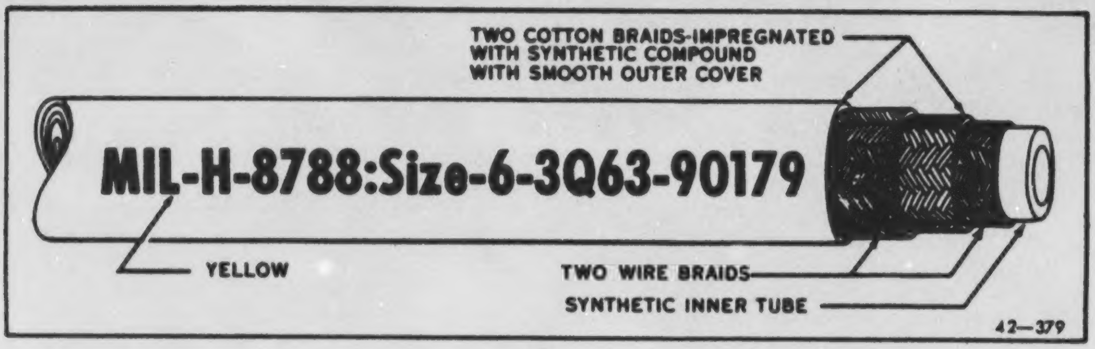


Figure 44. MIL-H-8788 high pressure hose construction.

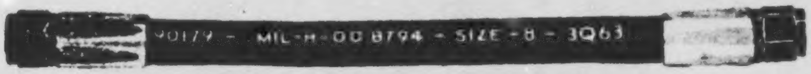
illustrates a piece of high-pressure hose (MIL–H–8788). Notice that it is very similar in construction to the medium-pressure hose except for an additional wire braid and smooth outside covering.

14-7. Teflon (Tetrafluoroethylene) hose is the latest advancement in the field of flexible hose. Its use is becoming widespread in hydraulic and pneudraulic systems. Like synthetic rubber hose, Teflon hose is manufactured for both medium-pressure and high-pressure systems.

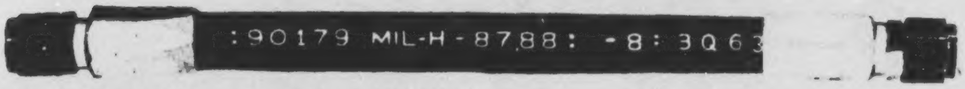
14-8. Teflon hose Specification MIL–H–27267 is used in hydraulic and pneumatic systems which do not exceed 1500 psi, except as specified in TO 42EI–1–1. The operating range of Teflon hose is approximately –65° to 450° F. This hose is manufactured with a smooth bore (firm, waxy feeling inner tube covered with corrosion-resistant steel wire braid. The hose is identified by a band spaced at 3-foot intervals. It is marked with the specification and manufacturer's code number. Factory fabricated hose assemblies are identified by a permanently attached metal band containing the following markings: Military Specification MIL–H–25579, operating pressure in psi, assembly part number, date of proof test, and the hose manufacturer's code number. Medium-pressure Teflon hose assemblies may be locally fabricated with the use of common handtools. The procedures are outlined in TO42EI–1–1–1.

14-9. The Teflon hose shown in figure 45 has the following distinctive advantages: (1) a practically unlimited storage time, (2) a greater operating temperature range, and (3) broader usage (hydraulic, fuel, oil, coolant, water, alcohol, and pneumatic systems).

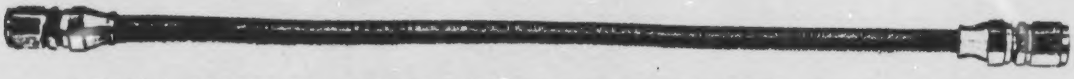
14-10 Now, let's describe the fabrication of medium-pressure rubber and Teflon hoses and



MEDIUM PRESSURE HOSE ASSEMBLY PART NUMBER MS 28741-8-0146



HIGH PRESSURE HOSE ASSEMBLY PART NUMBER MS 28759-8-0154



MEDIUM PRESSURE TEFLON (TETRAFLUOROETHYLENE) HOSE ASSEMBLY

42—380

Figure 45. Types of hose assemblies.

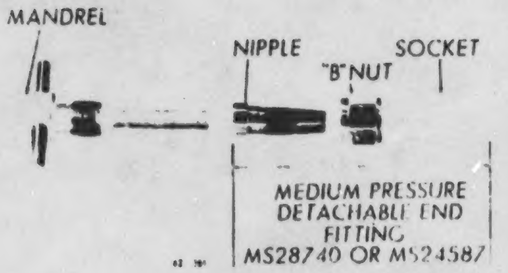


Figure 46. Mandrel and medium-pressure end fittings.

follow with a discussion of the high-pressure rubber hose. Figure 45 shows completed medium- and high-pressure rubber hoses.

14-11. **Fabrication of Medium-Pressure Rubber Hose Assemblies.** Common tools and equipment needed for assembling medium-pressure hose assemblies by hand are as follows: standard vise, oil can, hacksaw with a fine-toothed blade of 32 teeth per inch (or a hose cutoff machine P/N F-1730), and appropriate open-end wrenches. Special tools and equipment needed are a hand assembly toolkit (mandrels) P/N S-1051, a hydraulic hose testing unit, and an electric vibrator pencil P/N 11-100. Now let's discuss the use of these tools and equipment by showing how hose assemblies are fabricated.

14-12. After you have selected the proper size bulk hose (MIL-H-8794), get the mandrel and end fittings (MS28740 or MS24587 medium-pressure). A medium-pressure hose end fitting is shown in figure 46. Medium-pressure fittings may be reused if serviceable; however, do not intermix sockets and nipples (from one manufacturer to another), and never reuse the hose. To obtain the correct length of the cut hose, lay the two assembled fittings on a flat surface. Lay them the required distance apart to make the overall length of the desired assembly. Measure from the end of the flared or flareless portion of the end fittings to determine the length of the assembly. This is shown in figure 47. MS28760 and MS28761 fittings have a notch cut on the outer face of the socket corresponding to the shoulder depth. Measure from notch to notch to obtain the length of the cut hose material. Medium-pressure fittings do not have the notch.

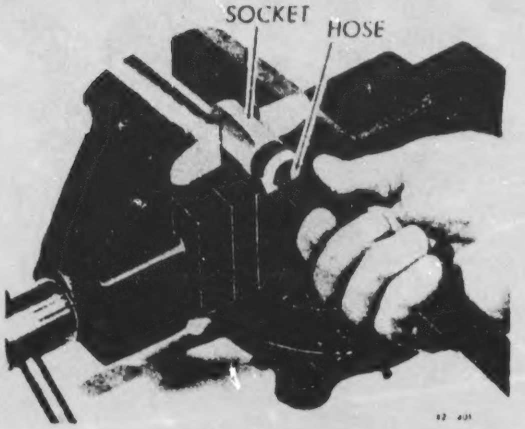


Figure 48. Hose installed into medium-pressure socket.

Measure inside the socket to the shoulder and place a pencil mark on the outside of the socket to indicate the shoulder location.

14-13. *Installation of end fittings.* After the hose is cut to the proper length, you are ready to install the end fittings. Place a socket in a vise and screw the hose into the socket counterclockwise, as shown in figure 48. This is continued until the hose bottoms on the shoulder inside of the socket. The hose is then backed off one-quarter of a turn. This allows the nipple and mandrel to slide into the hose. If you did not back off the hose, it would be very difficult to install the nipple. You next tighten the nipple and nut to the mandrel (fig. 49). Be sure to torque sufficiently so that the nipple will turn with the mandrel. This torque is necessary to prevent the nipple from slipping when it is installed in the socket and hose. Next, lubricate the inside of the hose and the outside of the nipple with oil Military Specification MIL-L-7870, as shown in figure 50. This is to allow the nipple to slide into the hose liner without cutting it. Now screw the nipple clockwise into the socket and hose, using a wrench on the hex of the mandrel (fig. 51). Stop turning the nipple when the proper clearance is reached (1/32 (0.031) to 1/16-inch (0.062)). The clearance is measured between the back of the nut and the face of the socket. After the proper clearance is obtained, loosen the B nut

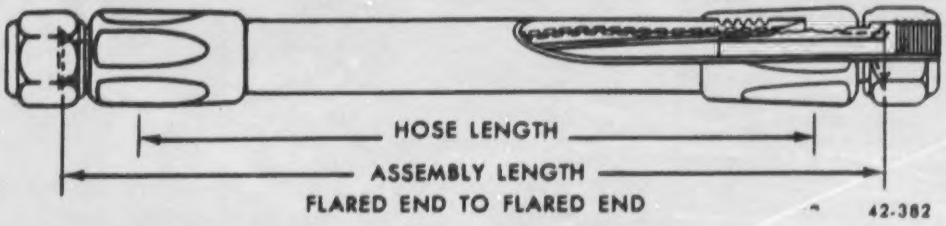


Figure 47. Hose and hose assembly measurements.

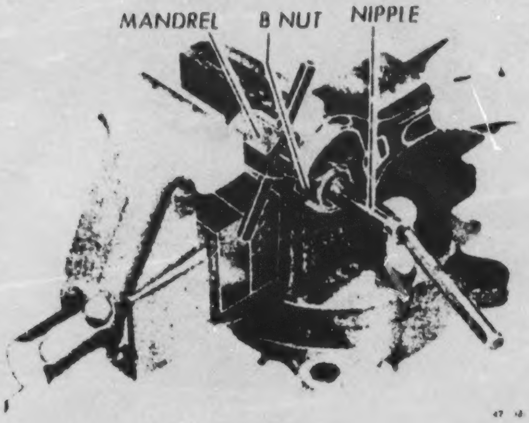


Figure 49. Tightening nipple and nut on mandrel.

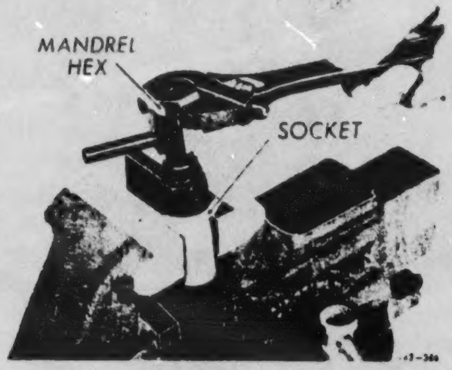


Figure 51. Installing medium-pressure nipple into rocket and hose.

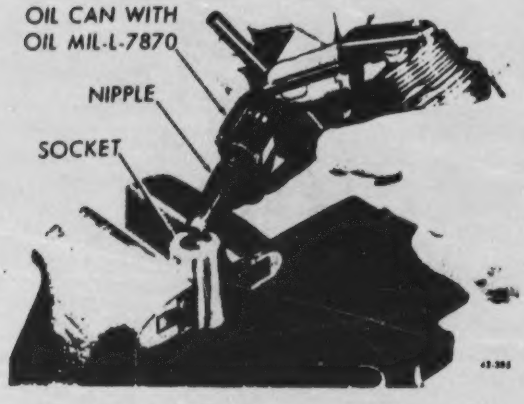


Figure 50. Lubricating medium pressure nipple.

and remove the mandrel. Install the other end fitting in the same manner. Then clean out the inside of the hose assembly with dry, compressed air. Inspect the hose assembly for any foreign material. Sometimes it may be necessary to flush the inside of the hose assembly to remove any foreign material.

14-14. *Proof pressure testing medium-pressure hose assemblies.* The next step is to proof pressure check the hose assembly. Any hydraulic testing unit may be used. The proof pressure is much higher than regular operating pressure. As an example, the operating pressure of a size 8 hose is 2000 psi. It is proof pressure tested an 4000 psi. A very important precaution when proof checking a hose is to use a heavy plastic cover over the hose assembly. This provides protection for the person inspecting the hose in case it should rupture. Proof pressure varies according to the size of the hose to be tested. (This is illustrated in TO 42E1—1—1.) The proof test pressure is maintained for a minimum of 30 seconds. Then, while maintaining this pressure, the assembly is checked for evidence of seepage. Hose assemblies showing evidence of seepage will be rejected. Completed medium-pressure hose assemblies will resemble the one previously shown at the top in figure 45.

14-15. *Marking medium-pressure hose assemblies.* To provide positive dates for replacement purposes, certain markings must be made on all medium-pressure hose assemblies. For example, the month and year of installation. Also the manufacturing date and activity making the hose. This information is etched on one flat surface of each end-fitting socket before installation on the aircraft. The activity fabricating the assembly is identified first by the base name etched on it, plus the first letter of the home state, i.e., Chanute, Illinois (ChI). An example of etching is as follows:

5--68 ChI
3--67

When medium-pressure end fittings are reused, previous etchings must be obliterated and newer dates etched on the next flat surface of the socket.

14-16. *Assigning part numbers to medium-pressure hose assemblies.* Completed medium-

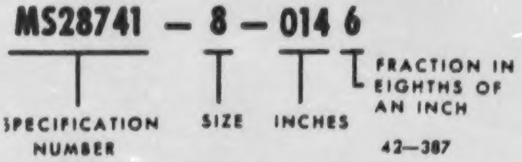


Figure 52. Part number of medium-pressure hose assembly.

pressure hose assemblies are given part numbers such as MS28741−8−0146. Specification MS28741 (in accordance with TO 42E1−1−1) tells us that medium-pressure hose is used. The −8 denotes the size of the hose and fittings. The numerals −014 denotes the length of the assembly in inches. The last digit, 6, is in eighths of an inch. Figure 52 is a detailed picture of the part number. A quick reference to this part number tells us we have a medium-pressure hose assembly, size 8, 14 3/4 inches long.

14-17. **Fabrication of Medium-Pressure Teflon Hose Assemblies.** Common tools and equipment needed for assembling medium-pressure Teflon hose assemblies by hand are as follows: standard vise, hacksaw (with a fine-toothed blade of 32 teeth per inch), hose cutoff machine P/N F−1730, masking tape, and wrenches (open-end or adjustable jaw). Special tools and equipment needed are a hydraulic testing unit and an electric vibrator pencil P/N 11−100. Assembly mandrels are not needed for hand assembly of fittings with this hose. Lubrication is not needed for MIL−F−27272 fittings; components are permanently dry-film lubricated. Now let's discuss the use of these tools and equipment by showing how hose assemblies are fabricated.

14-18. One of the first steps in the fabrication is to select the proper size bulk hose (MIL−H−27267), and end fittings (MS27061−, flared straight fitting). Medium-

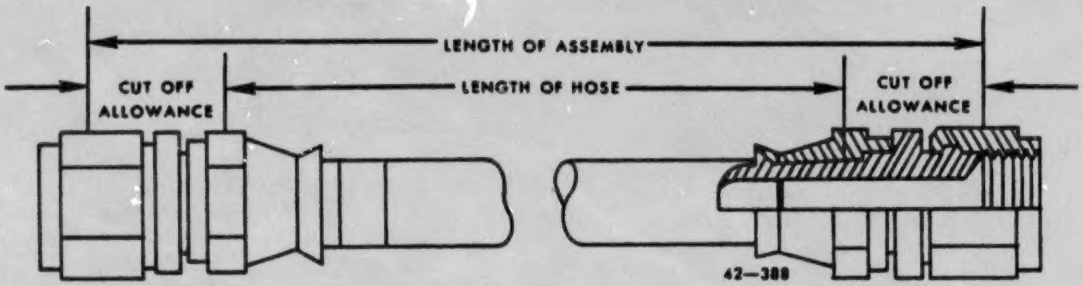


Figure 53. Teflon hose assembly measurements.

MS SWIVEL NUT FITTINGS					MS FLANGE FITTINGS		
	A	B	C		D	E	F
SIZE	ST	45°	90°		ST	45°	90°
-3	0.76	1.08	0.86				
-4	0.74	1.18	0.91				
-5	0.77	1.22	0.97				
-6	0.81	1.29	1.03				
-8	0.93	1.79	1.31		1.27	1.25	1.21
-10	1.05	1.58	1.41		1.35	1.42	1.41
-12	1.13	2.05	1.92		1.55	1.90	1.92
-16	1.30	2.14	2.05		1.61	1.98	2.05
-20	1.44	2.42	2.34		1.69	2.22	2.34

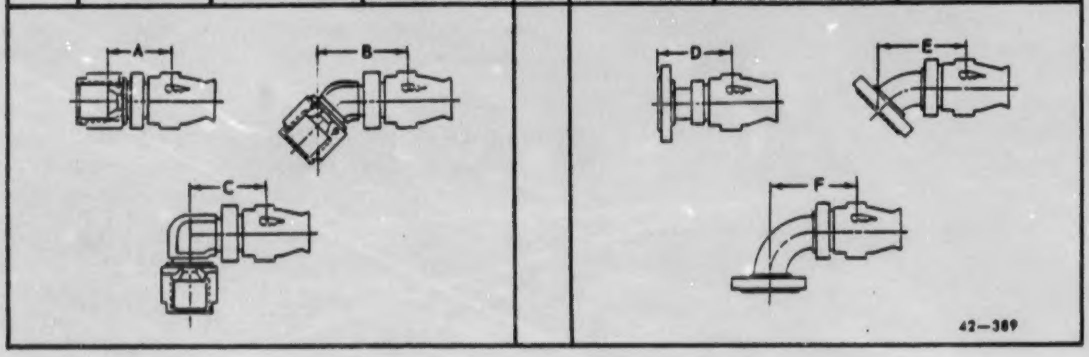


Figure 54. Teflon hose cutoff factors (in inches).

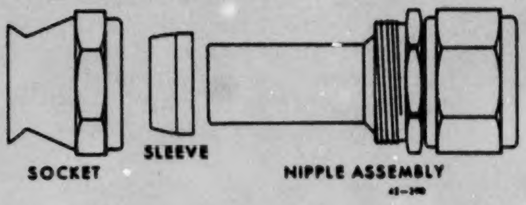


Figure 55. Teflon medium-pressure end fitting.

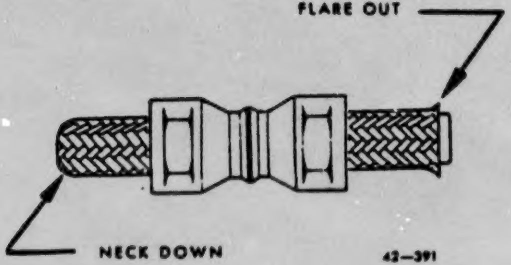


Figure 56. Sockets, skirt-to-skirt.

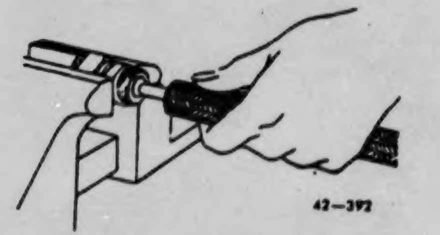


Figure 57. Size, tube and flare braid.

pressure fittings may be reused if serviceable (check closely the sealing surface of sleeve, nipple, and socket for damaged threads or distortion). NEVER reuse hose Specification MIL–H–27267. Next, we need to determine the length of hose to cut off. Refer to figures 53 and 54 for the end fitting cutoff allowance (the chart shown is from TO 42E1–1–1). The cutoff allowance for each end (as indicated by the chart in fig. 54) must be subtracted from the assembly length. For example, suppose we wanted to make a size 4 hose with straight fittings 15 1/2 inches in length. Referring to figure 54, we find that the cutoff allowance for each end is 0.74 inch times 2 end fittings, which would be 1.48 inches. This requires 14.02 inches for the hose without fittings. To prevent flareout of the wire during cutting, place a piece of masking tape around the hose cutoff point. After the hose is cut to the proper length, the tape must be removed. Figure 55 shows the socket, sleeve, and nipple assembly that make up the end fitting for Teflon hose assemblies. Place two of the sockets skirt-to-skirt as shown in figure 56.

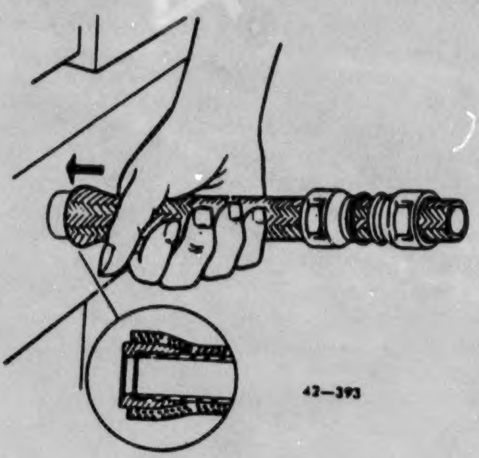


Figure 58. Inserting sleeve.

Then work the hose through the sockets with a pushing, twisting motion. Inserting the "neck down" end will make assembly easier. Remove the hose and sockets from the vise. Place the nipple assembly in the vise. Push the hose onto the nipple as shown in figure 57, to size the tube inside diameter (I.D.). This aids in separating the wire braid from the tube. Remove the hose from the nipple. Carefully insert the sleeve between the wire braid and tube outside diameter (O.D.). Insure that no wires are trapped between the sleeve and tube O.D. Complete inserting the sleeve by pushing the end of the sleeve against a flat surface. Do this until the tube bottoms against the shoulder in the sleeve I.D. (see fig. 58) . Next size the tube to the nipple. This is done by pushing the tube over the nipple until the sleeve bottoms against the nipple chamber. Remove and recheck to be sure the sleeve is still in place. Again push the tube onto the nipple and bottom of sleeve against the nipple chamber. Slide the socket foreward and engage the threads by hand. Remove the assembly from the vise and regrip the socket in the vise. Using a wrench on the nipple, tighten it to a gap of 1/32 inch from the socket; gap may vary from 0.025 to 0.045 inches (see fig. 59) Install the other end fitting in the same manner. Then clean the inside of the hose assembly. Use dry, compressed air to blow out foreign matter. Again inspect the hose assembly for any foreign material.

14-19. The next stop is to proof pressure check the hose assembly. This will be done in the same manner as for rubber hose. Use the same safety precautions as those for medium-pressure rubber hose assemblies. Proof pressure charts may be found in TO 42E1–1–1. They list proof pressures according to hose material and size. And, in some cases, they list according to the system that it will be used in, such as egress.

14-20. Special precautions must be adhered to for cleaning egress hose assemblies. When hydraulic fluid has been used for proof test, flush the hose assemblies thoroughly with trichloroethylene (minimum of 2 times). All evidence of hydraulic fluid must be removed. Allow cleaning fluid to drain; then thoroughly dry with compressed air.

14-21. **Fabrication of High-Pressure Rubber Hose Assemblies.** High-pressure hose assemblies are authorized for local manufacture. This is true only when qualified personnel and adequate equipment are available. Personnel assigned to manufacture high-pressure hose assemblies should be trained in assembly procedures. The safety hazards are increased greatly with the use of high pressure hose. This is not only true in its manufacture but also in its installation.

14-22. Fabricating high-pressure hose requires all of the tools used with medium-pressure hose except for a different mandrel. The mandrel for high-pressure hose has a part number of F−2065−8D (size −8). These mandrels come in sizes −4 through −16. In addition you will also need a wire brush (or soft wire wheel) and a hose cutting jig.

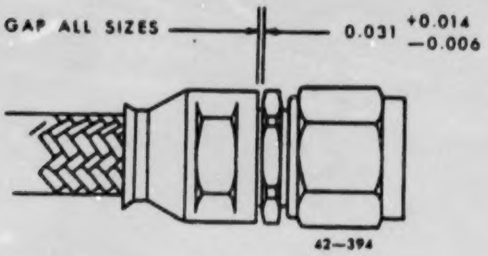


Figure 59. Tightening socket.

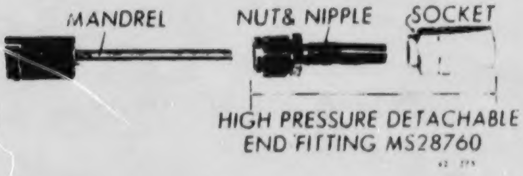


Figure 60. Mandrel and high-pressure end fitting.

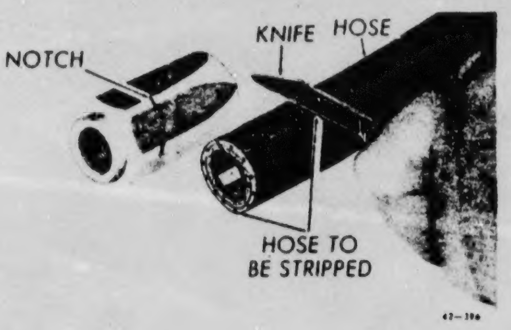


Figure 61. Marking the hose which will be confined inside of socket.

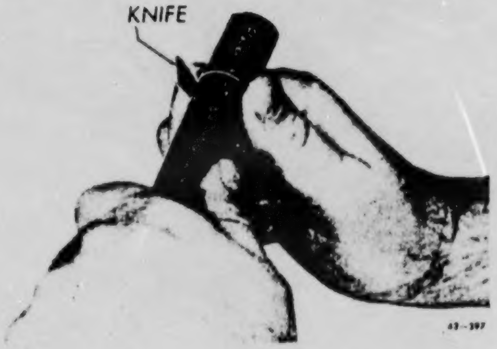


Figure 62. Cutting around hose to wire braid.

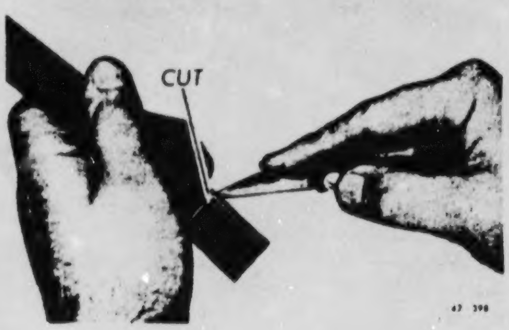


Figure 63. Cutting hose lengthwise.

14-23. The first steps in fabrication are to select the proper size bulk hose (MIL−H−8788), mandrel, and end fittings (MS28760 or MS28761). A high-pressure hose end fitting is shown in figure 60. In high-pressure systems, you never reuse end fittings or hose. Next, determine the correct length of hose required. The same procedures apply that were discussed for medium-pressure hose. After determining the correct length, cut the hose squarely. This is done by clamping it in a cutting jig and using the cutoff machine or a fine-toothed hacksaw. Then use compressed air to clear the hose of cutting residue. Figure 61 shows how to mark the hose to insure the proper outer covering removal. Place the socket against the hose as shown. Align the notch on

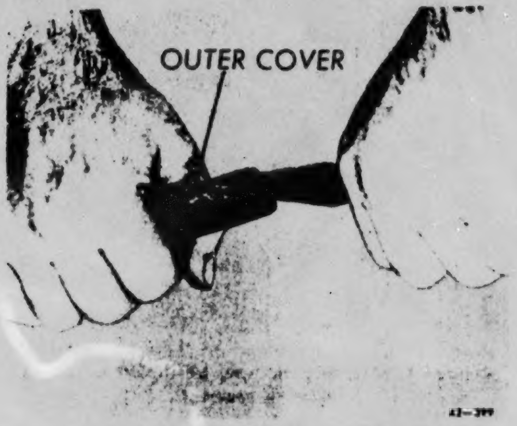


Figure 64. Twisting outer cover off high-pressure hose (MIL-H-8788).

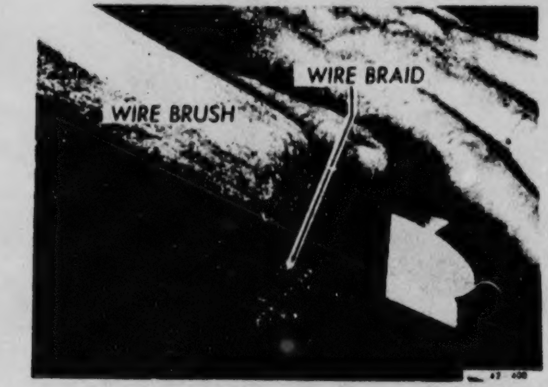


Figure 65. Removing rubber particles.

the socket with the end of the hose and mark as shown in figure 61. This amount of hose outer cover is to be stripped. Now refer to figure 62. Using the knife as shown, cut around the hose through the outer cover to the wire braid. (Make certain that the cut is to the wire braid.) Then slit this section of the outer cover lengthwise, as shown in figure 63. Next, pry up the outer cover with the knife. Then use the pliers to twist off the cover, as shown in figure 64.

14-24. Use a wire brush , as shown in figure 65, or soft wire wheel to remove all the rubber particles adhering to the wire braid. Be extremely careful during this operation to insure that the wire braid is not loosened, frayed, or flared when brushing. Next, place the socket in a vise and screw the hose into it, turning counterclockwise until it bottoms. This is shown in figure 66. Then back off the hose 1/4 turn. Avoid excessive turning of the hose in aluminum sockets. It will tend to grind away material from the buttresses inside the socket. Next, insert the mandrel into the nipple assembly. Lubricate the inside of the hose and nipple

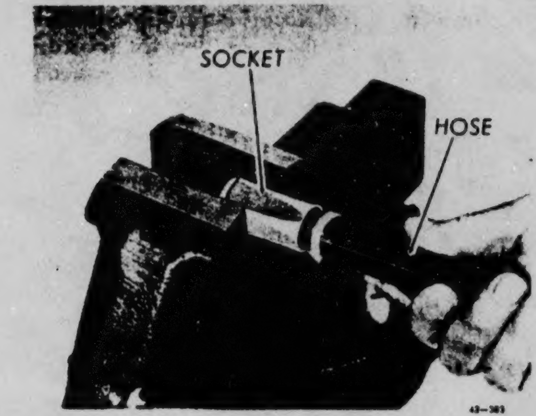


Figure 66. Installing high-pressure hose into socket.

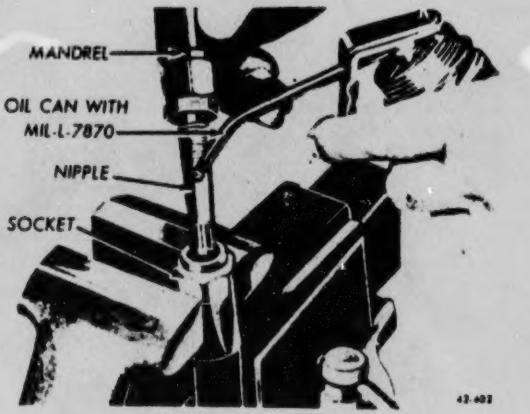


Figure 67. Lubricating high-pressure nipple and inside of hose

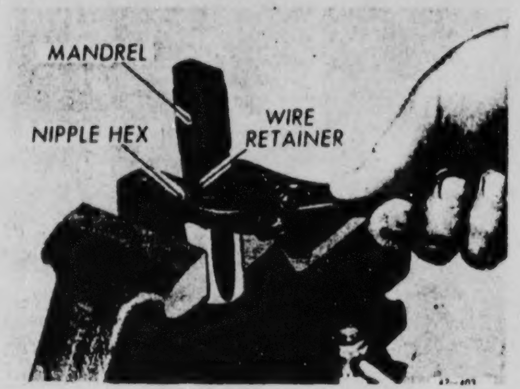


Figure 68. Installing high-pressure nipple into socket and hose.

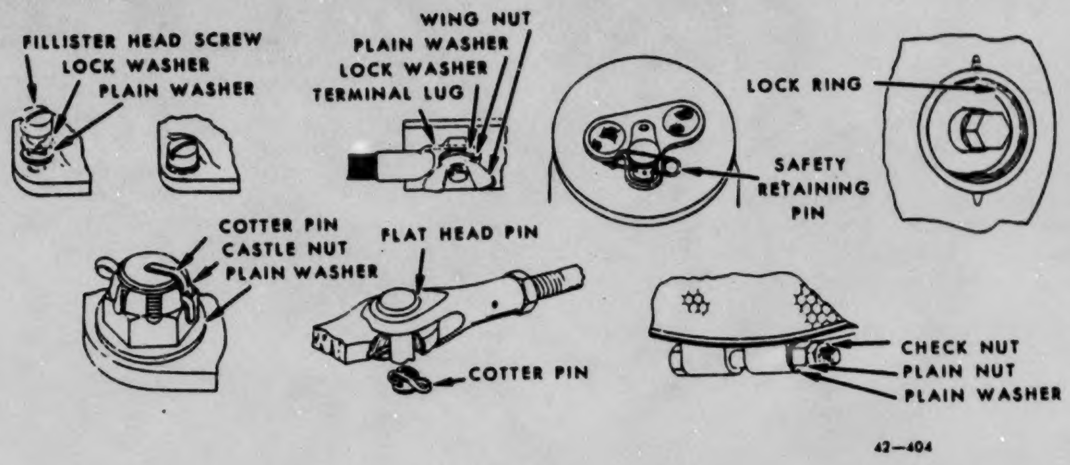


Figure 69. Safetying devices.

threads liberally, using oil Military Specification MIL–L–7870. These previous two steps are illustrated in figure 67. Then screw the nipple into the socket and hose, using a wrench on the nipple hex, as shown in figure 68. The nipple hex should bottom against the socket face. The B nut should rotate freely when the mandrel is removed. The clearance between the nipple hex and the B nut is provided for when the end fittings are manufactured. The B nut is held on the nipple with a wire retainer that maintains the proper clearance. (The B nut does not come off as it did on the medium-pressure end fitting.) After installing both end fittings, clean the hose aseembly internally, using dry, compressed air. Visually inspect the assembly internally to insure that there is no cutting of the inner tube. Also, check for a minimum bulge diameter of the inner tube. (Minimum bulge diameters for the various sizes of hose are found in TO 42E1–1–1.)

14-25. *Proof pressure testing high-pressure hose assemblies.* The host testing unit is used to perform the proof pressure test. Use the same safety precaution of installing a plastic cover as over the medium-pressure hose assembly previously explained. The proof pressure must be maintained for a period of not less than 1 minute and not more than 5 minutes. (Proof pressure varies according to the size of hose.) During this test period, check the hose for evidence of seepage. Hose assemblies showing evidence of seepage must be rejected. Under no condition will any adjustment of the end fitting be made on the completed assembly.

14-26. *Assigning part numbers to high-pressure hose assemblies.* Completed high-pressure hose assemblies are given part numbers similar to those for medium-pressure hose assemblies, the exception being the specification number. An example of a high-pressure hose assembly part number is MS28759–8–0154, as shown previously in the center of figure 45. This specification number tells us that we are using high-pressure hose MIL–H–8788 and end fittings MS28760. Again, the –8 tells us the size and the –0154 tells us that it is 15 1/2 inches in length. If we were to assemble high-pressure hose using end fittings MS28761, our hose assembly part number would be MS28762–8–0154. This tells us that we have a high-pressure hose assembly with flareless fittings attached instead of AN fittings (MS28760) for flared tube.

14-27. *Marking locally manufactured high-pressure hose assemblies.* Markings on the hose will be made in the same manner as with medium-pressure hose.

14-28. **Precautions To Be Observed Before Installing Hose Assemblies.** You must observe certain precautionary measures before installing medium- or high-pressure hose assemblies. For example, you should always inspect the hose assembly for serviceability. Also check it internally for foreign material. In addition, high-pressure hose assemblies must be proof tested before they are installed.

14-29. **Inspection of Medium- and High-Pressure Hose or Hose Assemblies.** All rubber (synthetic) hose or hose assemblies must be inspected for age and deterioration prior to installation. However, Teflon hose assemblies are considered chemically inert; therefore they are exempt from shelf-life age control. Inspection and replacement of installed hose assemblies shall be made according to the aircraft inspection requirements. Also inspect for signs of deterioration. Signs of deterioration are as follows: separation of the rubber cover or braid from the inner tube or wire braid; cracks, hardening, and lack of flexibility. Weather checking of the cover, which does not expose the fabric, will not cause immediate failure. However, as a safety precaution, replace hose when cracks are deep enough to expose the fabric. Because of varying conditions, replacement of hose assemblies is made at the discretion of the inspector. Hose assemblies using MIL—H—8794 or MIL—H—8788 hose must be replaced when any portion of the metal reinforcement is exposed or damaged. It is also replaced when the outer cover becomes loose.

14-30. **Storage of Medium- and High-Pressure Rubber Hose.** The storage life of medium- and high-pressure hose MIL—H—8794 and MIL—H—8788 or complete hose assemblies is calculated from the date of manufacture stenciled on the hose (except for Teflon hose). The time limitation is 16 quarters (4 years) for airborne equipment. (Hose that is over 4 years old may be used on ground equipment.) In addition, it should be stored so that the oldest hose will be used first. Hose must be stored in a dark, cool, dry place where it is protected from excessive heat and exposure to strong air currents. The hose must be stored away from electric motors or other

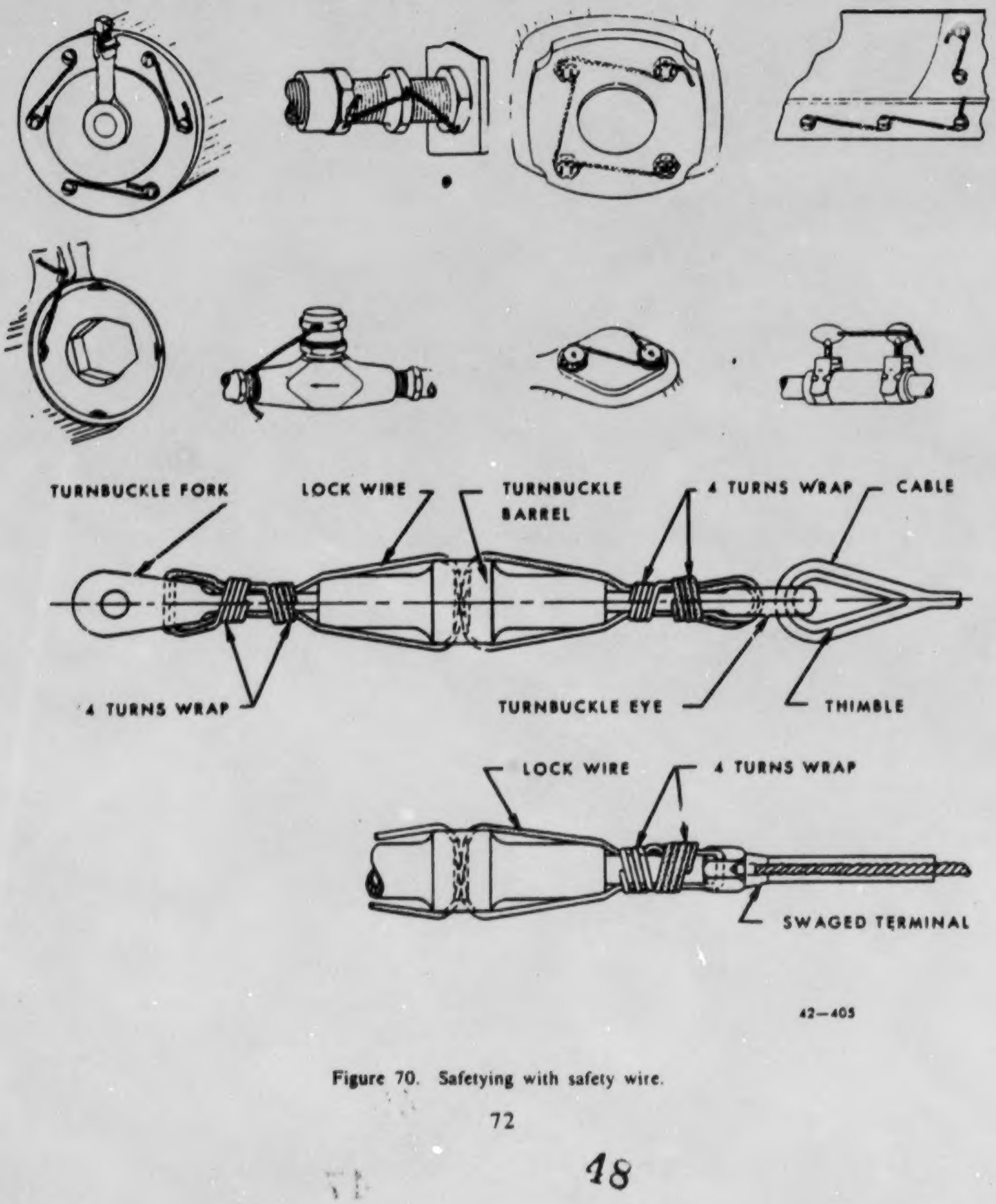


Figure 70. Safetying with safety wire.

equipment which gives off heat or ozone. All *bulk* hose should have the ends taped shut to prevent entrance of foreign material. Hose assemblies should have caps or plugs (metal or plastic) installed to keep them free of foreign material.

14-31. You should now have a comprehensive understanding of hydraulic fluids and plumbing materials. The next subject is safety.

15. Safetying Devices

15-1. Aircraft vibration tends to loosen or alter the adjustment of various parts, such as nuts, turnbuckles, and screws. Therefore, parts that are intended for disassembly or adjustment are safetied by some device. The safetying devices commonly used on aircraft are cotter pins, checknuts, lockwashers, safety pins, lockrings, and safety wire. Figure 69 shows these various safetying devices properly installed. Study it carefully. One safetying device incorrectly installed or left out can cause a failure of the component. This could possibly result in loss of the aircraft and the lives of the crew. This has happened! Now let's discuss each safetying device in detail.

15-2. **Cotter Pin.** The cotter pin is shown in figure 69. It is used for safetying various units such as castle nuts, clevis pins, and flathead pins. As an example, a 1/4-inch diameter bolt is drilled to receive a cotter pin 1/16 inch in diameter. Any installation requiring a safety pin smaller than 1/16 inch in diameter will use 0.041-inch steel wire. The cotter pin should be installed as illustrated in figure 69.

15-3. When removing the cotter pin, straighten the prongs. Then remove it with a cotter pin extractor or diagonal pliers. A cotter pin should never be reused.

15-4. **Checknut.** The checknut gains its safety factor by friction between metals. The checknut is tightened down after the plain nut has been tightened to the specified torque. The plain nut should be held with another wrench to prevent it from turning while the checknut is being tightened.

15-5. **Lockwasher.** A lockwasher maintains its safety factor by exerting spring pressure on a nut or screw. Because the threads of the screw or bolt are kept under tension, they resist any tendency of the bolt or screw to turn.

15-6. **Safety Pin and Lockring.** The safety retaining pin is used to lock such components as magneto covers, brush blocks, and lockpins. The pin locks either a screw or a unit to a housing. The safety pin prevents the unit or screw from turning or moving from its respective position.

15-7. The locking is used to hold end plates or retaining plates in the respective housing. This is done by installing the lockring in a groove after the end plate or retaining plate has been installed. It is held in the grove by spring tension.

15-8. **Safety Wire.** Safety wire and cotter pins are the most commonly used safety devices. Safety wire may be obtained in either copper or steel. The units to be safetied will determine the type of safety wire to be used.

Safety wire is generally applied by twisting. It must be taut and twisted close to the parts. In all applications, the wire should be arranged to oppose any loosening of the part. Figure 70 shows various methods and uses of safety wire. Study this figure carefully. The twisting can be done by hand or, when available, by special pliers.

15-9. Several different methods of safety wiring turnbuckles are in use. However, a standard procedure has been adopted by the armed services as the preferred method. This preferred method is illustrated in figure 70. Prior to safetying, check the turnbuckle for proper adjustment. Both terminals should be screwed an equal distance into the turnbuckle barrel. No more than three threads should be exposed outside the barrel. After the turnbuckle is adjusted properly you are ready to safety. To safety, start by inserting two pieces of safety wire in the center hole of the turnbuckle. Then bend the ends of the wires 90° toward the ends of the turnbuckle barrel. Then pass them through the hole in the turnbuckle eyes or between the jaws of the turnbuckle fork, as applicable. Wrap the wires four times around the shank, binding the wrapped wires in place.

15-10. When safetying a swaged terminal, pass the wire through the hole provided. Then loop the wire over the free end of the other wire; both ends must be wrapped around the shank, as shown in figure 70.

CHAPTER 6

Maintenance Tools

FOR WANT OF A NAIL the shoe was lost, for want of a shoe the horse was lost, for want of a horse the battle was—oh well, you know that story. It's been handed down through the years, and since no one has contested it, it's been accepted as fact. But the tale has been retold so many times that it's just possible the facts got garbled somewhere enroute.

2. Maybe the battle was lost for the lack of a proper tool to drive the nail to fasten the horse's shoe.

3. There were probably kegs and kegs full of nails at the local battlefield blacksmith shop. But the right tool for the job was important in those days too. Maybe the battle was lost because that tool wasn't used at the critical time.

4. Since the days when horses trod the battlefield, the proper use of handtools has grown even more important. For example, the maintenance of modern aircraft absolutely demands that the correct tool for the job be used—and used right! When the wrong tool is used, or even when the right tool is used incorrectly, serious accidents can result. The following near accident shows what can result from the wrong use of handtools.

5. A technician working in the third crew station of a B–58 misplaced a 4–inch screwdriver. Later, when he found out that the tool was missing, he searched for it, but didn't find it. The technician then committed two errors. First, he gave up the search, and second—but more serious—he failed to report the missing tool. A short time later, another technician, not knowing that anything was wrong, entered to do some work. One of the tasks was to move the seat up and down. This was to insure that the interphone cable had enough slack not to interfere with seat travel. When the technician moved the seat for this check, pandemonium and turmoil broke loose. The missing screwdriver was no longer lost. It was discovered jammed in the seat belt initiator tripping device. When the technician activated the seat position motor it caused the seat belt initiator to fire. This, in turn, caused the seat separator initiator to fire a moment later. Fortunately, this story of the misuse of a tool has a happy ending. The technician made a fast exit from the third crew station unhurt. Not all stories regarding the misuse of tools have such pleasant endings. Therefore, it is important that you realize how a terrible accident can have such a simple beginning.

6. This brings us to the subject of handtools. Countless volumes have been written on the subject of the proper use and care of handtools. Even so, the plain fact is that some mechanics think that handtools are so simple that no one needs to bother about pointing out the right and wrong way of using them. Understandably, a mechanic who considers himself a professional sometimes resents unasked for advice. Especially such as on tools or any other subject he considers to be within his domain. This attitude is a common fault among people in many fields who consider themselves professionals in their chosen specialty. This feeling is not restricted to mechanics. Nevertheless, the proper care, handling, and use of basic handtools is outlined in this chapter. If the subject matter in this chapter is studied with an open mind, it should pay dividends for both the mechanic and the Air Force.

16. Handtools

16-1. One of the outstanding characteristics of a good mechanic is the sound judgment he uses in caring for his tools. He prolongs the life of tools by always taking good care of them. Such good care includes periodically cleaning the tools. At this time, the mechanic should inspect the tools for serviceability. In this way he increases his efficiency and the quality of his work. Equally important, he uses each tool only for the purpose that it was intended.

16-2. If you were to ask this man how he manages to keep his tools in such good shape he might answer that he uses a checklist. This list could be written or it could be committed to memory. If it's a written list, it might look something like this:

- *a.* Keep tools as clean as possible when using them and be sure to clean them before putting them away.
- *b.* Have a place for each tool.
- *c.* Keep every tool in excellent condition.
- *d.* Make an inventory of tools after each job to prevent leaving anything in aircraft engines, ducts, wells, etc.
- *e.* Keep junk and unneeded tools out of toolbox.
- *f.* Keep toolbox securely locked and in a safe place when not in use.

16-3. **Screwdrivers.** One of the most misused tools is the screwdriver. Many mechanics seem to forget that there is a proper screwdriver for every job. Too often small screws are driven with a giant driver, and the result, of course, is a scored slot. Phillips and Reed and Prince screws take the worst beating, usually because the mechanic is too lazy to get the right driver. In addition, Phillips and Reed and Prince crosspoint screwdrivers are often used mistakenly, simply because they resemble each other. They are not interchangable because their tips are ground differently. Figure 71 shows the most common types of screwdrivers presently used.

16-4. It may come as a surprise to some people, but the screwdriver is intended for one, and only one, purpose: to loosen and tighten screws. The screwdriver, with its slender steel shank and wood or plastic handle, is designed to take considerable twisting force or torque. But it is not designed to be used as a lever, chisel, punch, or pry bar. The bending force on the shank plays havoc with the shape of the tool.

16-5. The tip of a correctly ground screwdriver should have the sides of the blade practically parallel. However, since it costs more money to grind a blade like this, most manufacturers taper the blade out to the shank body. A good trick is to dress the blade on an emery wheel so that the faces taper in very slightly for a short distance back of the tip. A screwdriver blade ground in this way will stay down the screw slot even under severe torque.

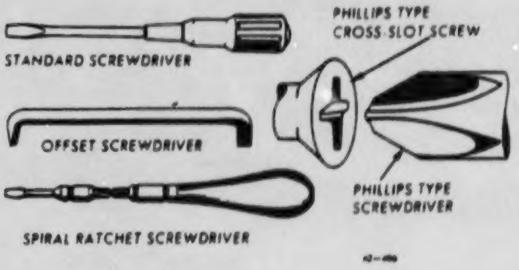


Figure 71. Commonly used screwdrivers.

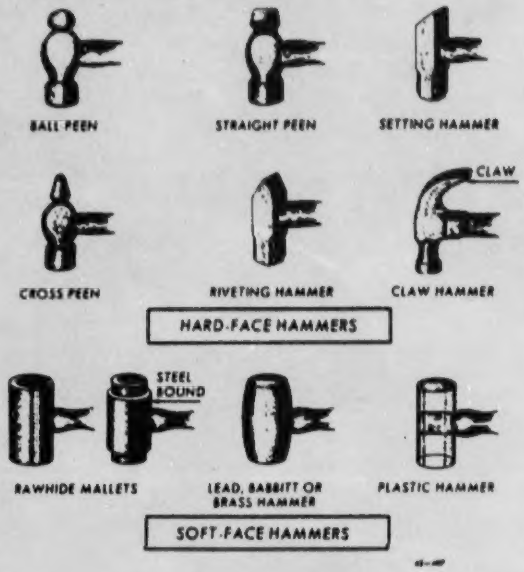


Figure 72. Commonly used hammers.

16-6. **Hammers.** There are many kinds of hammers, but the one most used by Air Force mechanics is the ball peen. These hammers are classified according to weight of the head without the handles. They usually weigh 4, 6, 8, and 12 ounces; and 1, 1 1/2, and 2 pounds.

16-7. Most beginners have a tendency to hold the handle too close to the head, "choking" the hammer. Holding the hammer like this reduces the force of the blow and makes it harder to hold the hammer head upright.

16-8. When you use a hammer on a machined or polished surface, always protect that surface. Place a piece of soft brass, copper, lead, or hardwood between the surface and hammer. For certain types of work there are special hammers made from rawhide, plastic, or brass that protect the surface. Never use the butt of the hammer handle for bumping, such as tapping a bearing into place. It may split the handle. Figure 72 shows the more commonly used hammers.

16-9. **Pliers.** Pliers rank close to screwdrivers as being the most misused handtool. No tool in your box can ruin more work than a pair of pliers. In fact, some experienced mechanics won't let an apprentice mechanic use a pair of pliers under any circumstances.

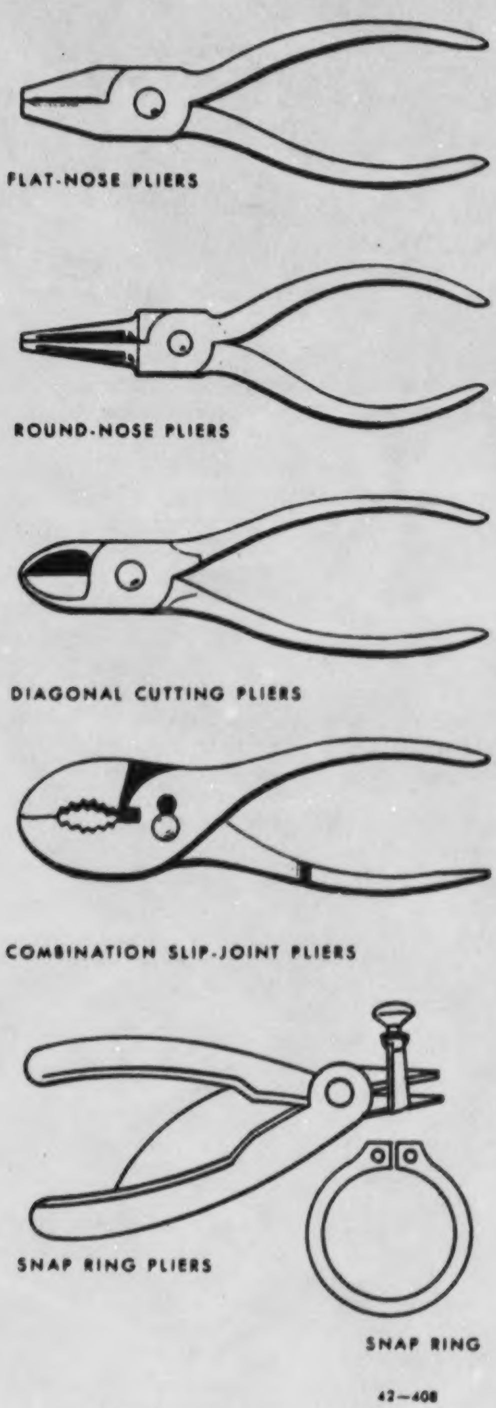


Figure 73. Commonly used pliers.

16-10. There are many types of pliers, but the most common is the 6-inch combination slip-joint pliers. These are also called combination pliers. These are shown in figure 73. Combination pliers come in 5-, 6-, 8-, and 10-inch sizes (the length of the handle determines the size). Some are made with side cutter arrangement for clipping cotter pins.

16-11. Under no circumstances should pliers be used on hardened surfaces to tighten or loosen a nut. If you do use them on such a hardened surface, you'll dull the teeth. Think of a pair of pliers as a *holding* tool, never as a tightening tool.

16-12. Other variations are the diagonal (dike) pliers and the long-nose pliers. Use diagonals for clipping cotters, pulling cotters from castellated nuts, and for spreading split ends of cotter pins.

16-13. The long-nose pliers—round, flat, or duckbill—will help you out of many a tight spot. One advantage is a long reach in a close place. Another pair of pliers that is a common tool for the hydraulic man is the snapring pliers. They come in several different sizes, both inside and outside type; that is, they are designed either to spread snaprings or to clamp them together.

16-14. **Wrenches.** There are many different kinds of wrenches that the skilled pneudraulic repairman must know how to use and care for. We shall focus attention on the open-end, box-end, adjustable-jaw, strap, spanner, socket, torque, and Allen wrenches.

16-15. *Open-end wrenches.* Solid, nonadjustable wrenches with openings in each end are called open-end wrenches. The upper portion of figure 74 shows one of these wrenches. About 10 open-end wrenches are commonly found in a toolbox. The openings normally vary from 5/16 to 1 inch in width.

16-16. The size of the openings between the jaws determines the size of the wrench. The smallest wrench in the ordinary set has a 5/16-inch opening in one end and a 3/8-inch opening in the other. Because of this combination, the wrench is called a 5/16- by 3/8-inch open-end wrench. These figures refer to the distance across the flats of the nut and not to the bolt diameter. Wrench openings usually measure 0.005 to 0.015 inch larger than the nominal sizes marked on the wrenches. This is so they will more easily slip on and off boltheads and nuts.

16-17. The smaller the openings in the wrench, the shorter the overall length. This proportions the lever advantage of the wrench to the size of the bolt or stud. With a given amount of pull on a wrench, a short length will produce less twisting or torque and will reduce the possibility of shearing or stripping the nut.

16-18. Open-end wrenches have their heads and openings at an angle to the body. Most are designed to be offset about 15°, but some wrenches are designed for a 22.5° offset. In case you wonder why wrenches are made this way, it is because this design provides for working in close quarters.

16-19. An elementary trick is that of "flopping" the wrench after every stroke; flopping consists of turning the wrench over. What had been the upper face is now facing down, and the angle of the head is reversed to fit the next two flats of the hex nut. This makes it much easier to loosen or tighten a nut. The 15° angle and flopping the wrench enable you to turn a nut even when the swing of the nut is limited to 30°.

16-20. Some special types of open-end wrenches have the angle of opening at 75°, whereas others are set at an angle of 90°. There are also special, thin open-end wrenches which have extra long handles that allow you to work in narrow spaces. Never use this type of wrench for any job that requires a lot of torque, because the handles won't take it.

16-21. Always *pull* on the wrench—never push. Pushing a wrench is dangerous. The threads could break loose unexpectedly and you'd wind up with some hide off your knuckles.

16-22. *Box-end wrenches.* The best feature about a box-end wrench is that it can be used in close quarters. This wrench is called a box-end wrench because it boxes or completely surrounds the nut or bolthead. The lower portion of figure 74 shows a box-end wrench. The box-end wrench may have 12 notches arranged in a circle. A 12-point wrench can be used to loosen or snug up a nut with a minimum handle travel of only 30°, whereas a 60° swing would be necessary in an open-end wrench.

16-23. Another advantage of the box wrench is that there is little or no chance of its slipping off the nut or bolt, because it completely encircles the nut or bolt head.

16-24. Another version of the box-end wrench is the cutaway box-end wrench, shown in figure 75. This wrench is specially designed for tightening plumbing connections. The cutaway enables the box to be slipped over the tubing and then positioned on the nut of the connection. This type of wrench has an advantage over an open-end wrench when tightening tube connections. It is that there is little chance of the cutaway wrench slipping off the nut.

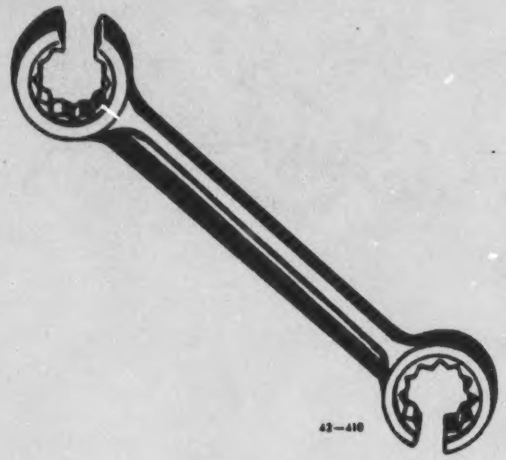


Figure 75. Cutaway box-end wrench.

16-25. *Adjustable-jaw wrenches.* Adjustable-jaw wrenches are those that have one stationary jaw and one adjustable jaw. Figure 76 shows two types of adjustable-jaw wrenches. The length of the handle determines the size of the wrench. For example, a 6-inch Crescent has a 6-inch handle, although its jaws open only to three-fourths of an inch. As the length of the handle increases, there is a proportional increase in the size of the opening of the jaws.

16-26. The Crescent wrench, shown in the lower portion of figure 76, is the most commonly used adjustable wrench. However, the Crescent wrench is not intended to take the place of standard open-end, box-end, or socket wrenches. It is primarily intended to be used when an odd-sized nut or bolt is encountered.

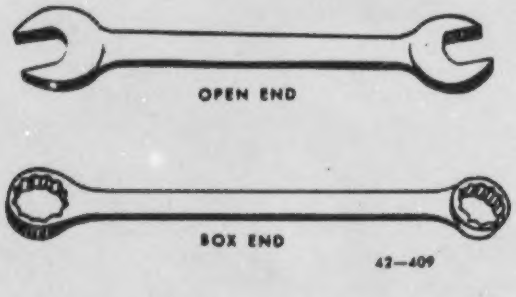


Figure 74. Open-end and box-end wrenches

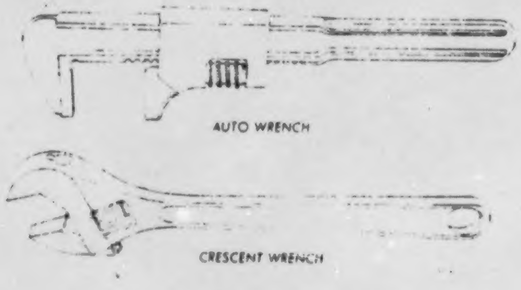


Figure 76. Adjustable-jaw wrenches.

Crescent wrenches are not built for hard service. They just won't take torque! To prevent breaking the tool, when you have to exert any amount of force apply it properly. Always remember to place the wrench so that the pulling force is applied to the stationary jaw side. The adjustable jaw should push. After you place the wrench, tighten the knurl so that the jaws fits the nut snugly. Usually, a set of Crescent wrenches includes 4-, 6-, 8-, 10-, and 12-inch wrenches. The same application technique also applies to the auto wrench.

16-27. The upper portion of figure 76 shows an adjustable-jaw type wrench which is generally referred to as the auto wrench. Some call it a knucklebuster, with reason. When force is applied, the jaws tend to spread and slip off the nut or bolt head.

16-28. *Strap wrenches.* The strap wrench consists of a bar with a strap attached to one end. It is used to hold or turn cylindrical parts without damage to the surface. Our most common usage would be to hold the barrel of an actuating cylinder or piston type accumulator while removing the end caps. A strap wrench is shown in figure 77.

16-29. *Spanner wrenches.* Spanner wrenches are special wrenches for special jobs. There are a number of types, some of which are shown in figure 78. The *hook spanner* is for a round nut that has a series of notches cut in the outer edge. The hook or lug is placed in one of the notches with the handle pointing toward the direction in which the nut is to be turned. Some hook spanner wrenches are adjustable and will fit nuts of various diameters. U-shaped hook spanners have two lugs on the face of the wrench to fit notches cut in the face of the nut or screw plug. End spanners resemble a socket wrench but have a series of lugs on the end that fit into corresponding notches in the nut or plug. Other spanners come in kits, with replaceable lugs or pins to fit a various combination of nuts and plugs.

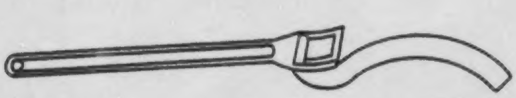


Figure 77. Strap wrench.

16-30. *Socket wrenches.* The socket wrench helps greatly in making a mechanic's work easier. The first socket wrenches were formed with an L or T handle as part of the wrench. Each size socket was a separate wrench. Today, however, there is an infinite variety of socket wrenches for every possible use and position.

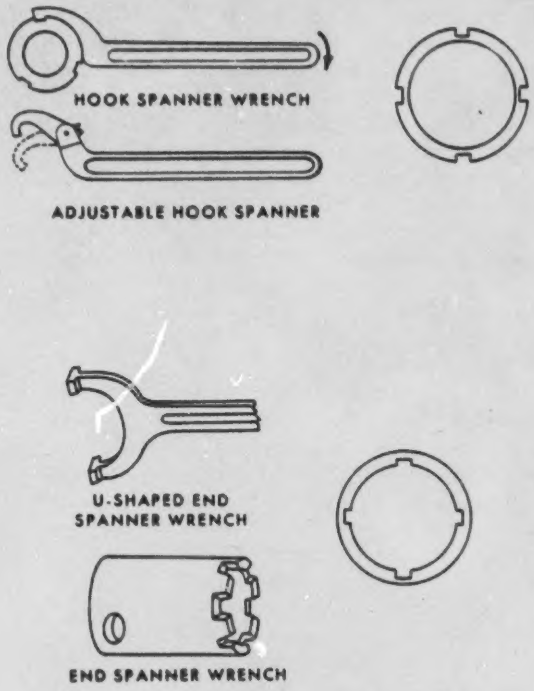


Figure 78. Spanner wrenches.

16-31. One thing to keep in mind when using socket wrenches is that they should never be overstressed. Never use an extension to lengthen a socket wrench handle to increase torque. Always use a socket that is big enough for the job—and by that we mean the drive size. Don't be in a hurry and use a 1/4-inch drive socket when it requires a 3/8-inch drive that is built for the heavy job. Figure 79 shows two 12-point sockets and the various extensions, universals, ratchets, etc.. used with the sockets. Sockets are also designed with 6 points. The advantage of the 12-point socket is that it must be swung only half as far before it can be refitted for another grip on a nut. For this reason, it can be used in close quarters. On the other hand, a 6-point socket holds the nut better. It offers less chance for wear because of the greater holding surface.

16-32. *Torque wrenches.* Torque wrenches are calibrated tools used to measure the force of pull (pounds) when tightening nuts or hose clamps. It can also be used for checking the breakaway torque of various driving units. The torque is expressed in either inch-pounds or foot-pounds. As a pneudraulic repairman, you will be required to use these wrenches when installing units. Units must be properly torqued, or else disastrous consequences may result.

16-33. The breakaway type torque wrench,

SPEED HANDLE
HINGE HANDLE
SLIDING TEE BAR
RATCHET
EXTENSION
DEEP SOCKET
STANDARD SOCKET
UNIVERSAL
42 444

Figure 79. Socket wrench set.

shown in figure 80, is commonly used by the Air Force. This type of torque wrench automatically releases when a predetermined torque value is reached. This torque wrench consists of an adjustable handle grip, a locking ring, a micrometer type adjustment incorporating a thimble marked for secondary increments, a spring tube marked for primary increments, and a drive assembly.

16-34. To set the breakaway type torque wrench to the selected value, unlock the handle grip by turning the locking ring. Then turn the handle grip either clockwise or counterclockwise until the graduation on the thimble aligns with the desired graduation on the tube. The handle grip and the thimble are machined from one piece of steel. Thus, they turn as a unit. After the adjustment is made, relock the handle grip by turning the locking ring.

16-35. When using the breakaway type torque wrench, always pull the wrench in a clockwise direction, applying a smooth and steady motion. When the torque applied reaches the predetermined torque setting, the wrench will automatically release, or "break," producing from approximately 15° to 20° of free travel. This release is distinct and indicates completed tightening action on the fastener.

16-36. There is another important thing to remember when using a torque wrench to tighten a series of nuts: never tighten one nut to the specified torque before starting to tighten the other nuts. Instead, tighten each nut a little until they all meet the specified torque. Nuts opposite (or diagonal to) each other should be tightened in sequence.

16-37. Organizational maintenance activities must have their torque wrenches tested once a month, or more often if usage demands. Local directives designate the shop to do the testing. The 30-calendar-day period is calculated from the date of the test. For example, a tool tested on 15 March 1968 will be due for retesting on 15 April 1968. A torque tool that is dropped or otherwise abused must be tested and recalibrated if necessary before further use. After each test, a color code strip is placed around the handle with the date, month, and year retesting is due.

16-38. *Allen wrenches.* Another type of wrench you may sometimes have occasion to use is the Allen wrench. This wrench is six-sided, L-shaped, and designed to fit into the recessed head of the setscrew or capscrew. Either end of one of these wrenches will fit into the recess, making its use possible where either a long or short reach is desired.

16-39. **Files.** Another tool that the pneudraulic repairman will likely use is the mill file. A mill file, shown in figure 81, is a hardened, high-carbon steel tool used for cutting, removing, smoothing, or polishing metal. Use a coarse file for soft metals and a smooth file for hard metals. The double-cut file gives a

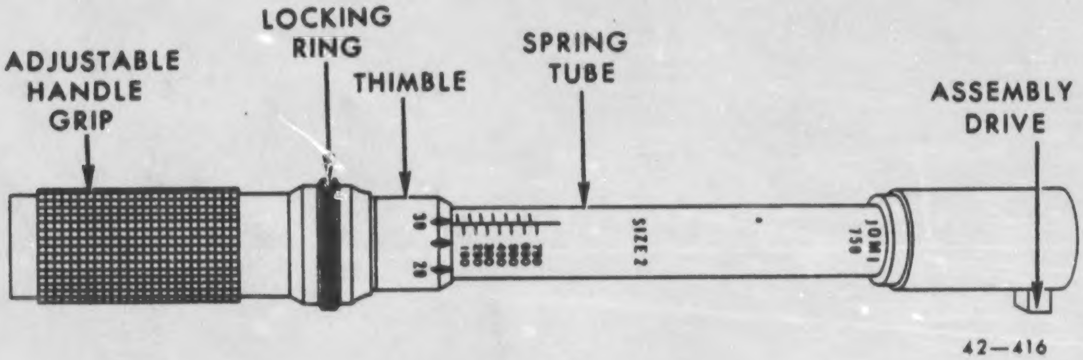


Figure 80. Breakaway type torque wrench.

smoother cut and will remove more material per stroke.

16-40. The mill file should never be used without a handle. Without a handle, if the file slips, the tang of the file may cut or stick in the palm of your hand. Remember, the real mechanic—the man who is careful in the way he goes about his work and uses tools—seldom has need for a first aid kit.

16-41. Whenever possible, clamp the part to be filed in a vise. In using a file, remember that the teeth are made to cut in one direction

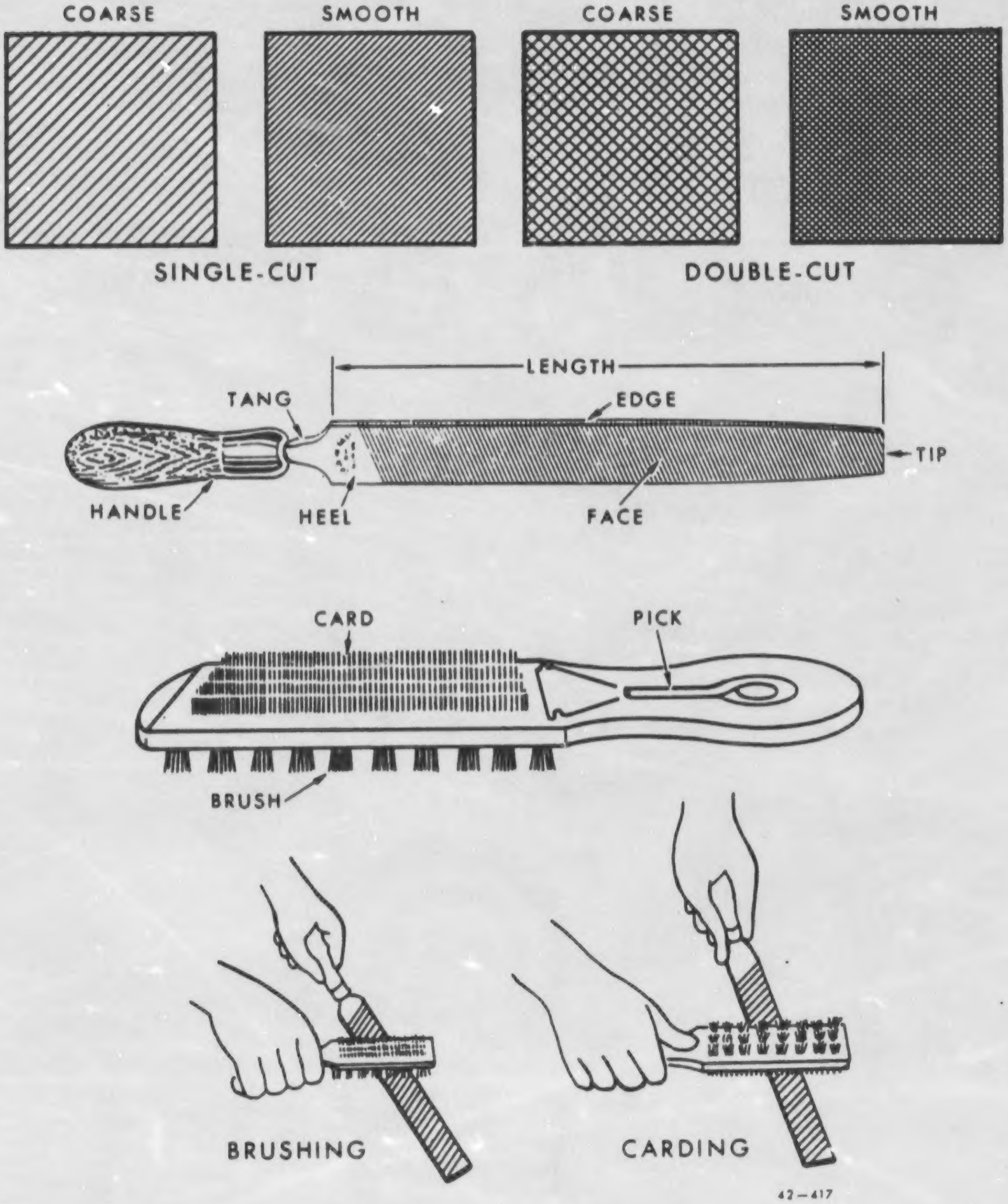

COARSE
SMOOTH
COARSE
SMOOTH
SINGLE-CUT
DOUBLE-CUT
LENGTH
TANG
EDGE
TIP
HANDLE
HEEL
FACE
CARD
PICK
BRUSH
BRUSHING
CARDING
42—417

Figure 81. File and file card.

only—when the file is being pushed forward. Use only sufficient pressure to keep the file cutting. All pressure should be relieved on the back stroke. Back stroke pressure serves only to help dull the cutting edges of the teeth.

16-42. In some shops they call a mechanic who drags a file on the back stroke a "shuffler," because he is like a man who is too lazy to pick up his feet when he walks.

16-43. Never use a file after the teeth become "choked" or clogged with particles of metal. To jar the filings, bump the tip of the file or the end of the handle on the bench every now and then while filing. This won't always get all the chips out, so the thing to do when the file gets "loaded" is to clean the teeth with a file card, as shown in figure 81. This is a brush with short, stiff wire bristles. If there are any chips left after using the file card, these should be dug out with a pointed cleaning wire called a pick or scorer. Usually a file card has one attached to the handle. Occasionally apply a light coat of oil to your files to prevent rust from forming.

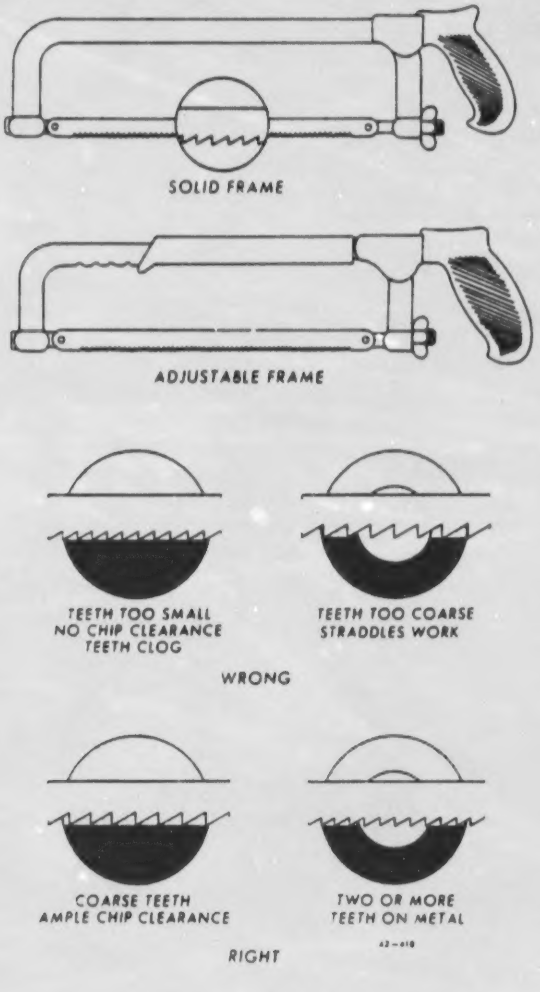


Figure 82. Hacksaws and blades.

16-44. **Hacksaws.** Hacksaws are often used by mechanics. Common hand hacksaws have either adjustable frames or solid frames, as shown in figure 82. Adjustable frames can be changed to hold blades from 8 to 16 inches long. Solid frames, although more rigid, will take only the length of blade for which they are made. This length is the distance between the two pins which hold the blade in place.

16-45. Hacksaw blades are made of high-grade, hardened and tempered tool steel. There are two types: the all-hard and the flexible blades. All-hard blades are hardened throughout, whereas only the teeth of flexible blades are hardened. Blades generally range from 7/16 to 9/16 inch wide and have from 14 to 32 teeth per inch. They are from 8 to 16 inches long.

16-46. Choice of the correct hacksaw blade for a certain job is determined by the type of material being cut. An all-hard blade is best for sawing brass, tool steel, cast iron, and other stock of heavy cross section. In general, a flexible blade is used for sawing hollow shapes and metals of light cross section, such as channel iron, tubing, tin, copper, and aluminum (refer to fig. 82). Coarse-toothed blades are used mostly for solid stocks, whereas fine-toothed blades are used for materials such as tubing, channel iron, and sheet metal. A blade with 32 teeth per inch is recommended for cutting thin-walled tubing and conduit.

16-47. After the correct blade has been selected and installed in the hacksaw frame, it should be moderately tightened. A blade that is tightened too tight will break easily when used. Next, mark the material that is to be cut. This can be done with a scriber, pencil, etc. If special accuracy is required, nick the material with a file and start the saw in the nick. Be certain that the work to be cut is gripped tightly in a vise, with the line of cut as close to the vise jaws as possible. When cutting angle iron or any odd-shaped material, start the cut so that the maximum number of teeth is engaged throughout the cut. When cutting aluminum tubing, make certain that the tubing is held firmly in the vise. Yet do not hold it so tightly that

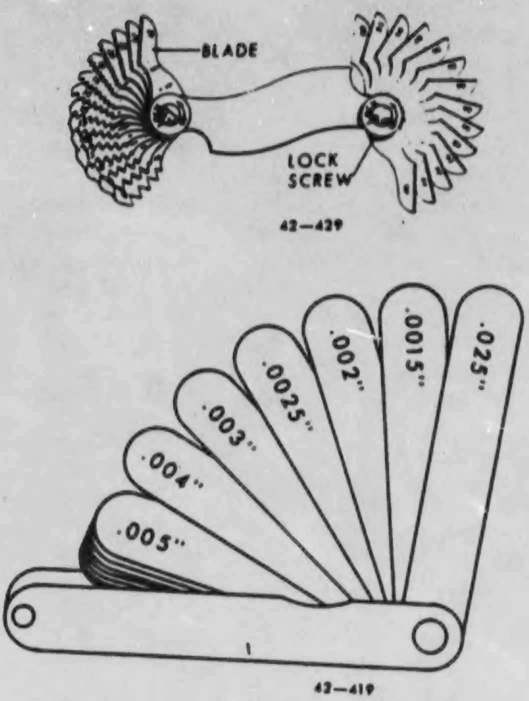


Figure 83. Thread and thickness gages.

the tubing will be squeezed out of shape. It is advisable to clamp the aluminum tubing between two pieces of wood or soft metal and saw through all three pieces, because this will prevent chattering and possible damage to the work. The hacksaw should be moved forward with a light, steady stroke. At the end of the stroke, relieve the pressure and draw the blade straight back. After the first few strokes, make each stroke as long as possible without striking the saw frame against the material being cut. The most effective cutting speed is about 60 strokes per minute. When the material is nearly cut through, relieve the pressure on the saw slightly. This is to prevent the teeth from catching.

16-48. The chief danger in using hacksaws is injury to the hand when a blade breaks. The blade will break if the mechanic bears down too hard on the cut or does not push the saw in a straight line. If the work is not tight in the vise, it will sometimes slip, twisting the blade enough to break it.

16-49. Much of this information about handtools may have sounded elementary to your experienced hands. But day after day, it is often the so-called experienced hand that is bungling the job with the wrong tool or the right tool carelessly used. Stop and THINK a minute. Experience and a little common horse sense will carry you a long way in the right direction. Special measuring tools such as thickness gages and micrometers are also commonly used by the pneudraulic repairman.

17. Special Measuring Tools.

17-1. As a pneudraulic repairman, you need to know how to read the various measuring devices that are used in your work. Sometimes you will have to make measurements in ten-thousandths of an inch. The correct use, care, and storage of measuring devices is necessary for long service and complete accuracy. Included among the tools that you may use are the thickness and thread gages shown in figure 83. The thickness gage is used to measure clearance between objects. A thread gage is very useful when matching nuts and bolts or when ordering replacement parts. The thread gage will measure the number of threads per inch; without such a gage it is often difficult to see the difference in bolts lying side by side. In this section we will discuss special measuring tools. We will focus on the use of micrometers, including the outside micrometer, inside micrometer, and depth micrometer.

17-2. **Outside Micrometer.** With the outside micrometer you can measure the outside dimension of an object, the thickness of a metal plate, or the outside diameter (O.D.) of a tube or piece of wire. The frame (figure 84) of the micrometer is made in different sizes to accommodate various objects. The size of the object that the micrometer can measure is generally stamped on the side of the frame. You can look at the micrometer and determine what size object it will measure. This is really not much of a task once you are familiar with micrometers. If your micrometer is marked with "0 – 1," then it is made to measure objects up to 1 inch in thickness; if it is marked with a "5 – 6," it is for objects measuring between 5 and 6 inches. Some frames may have a single number instead of a dual number. If the number is 3, the largest measurement to be taken with that micrometer is 3 inches. The range of the micrometer, then, is between 2 and 3 inches; the range is the distance between the largest and smallest measurements that can be taken with the tool. Micrometers usually have a 1-inch range, but some have a 1/2-inch range—from 0 to 1/2 inch, for example.

17-3. Now refer to figure 84 again, and let's see how an outside micrometer measures. The object to be measured is placed squarely between the anvil and the spindle. The anvil is fixed to the frame and is stationary with respect to it. Anvils are shaped according to the use to which the tool is put; they may be flat, rounded, or tapered on the end. The spindle is fastened internally to the thimble which, when turned, moves the spindle nearer to or farther from the anvil.

17-4. When the thimble is turned, it moves either inward or outward on the barrel. On the barrel are two series of graduations and a line. This line, which extends lengthwise along the barrel, is known as the revolution line. Perpendicular to this line are the major graduations. The major graduations are numbered 0, 1, 2, 3, 4, 5 on the tool with a 1/2-inch range; or 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 on the tool with a 1-inch range. Each of these major graduations represents 0.1 inch. Each of the smaller graduations (lines) on the barrel (there are three between each major graduation) represents 0.025 inch. The thimble will move laterally a distance equal to the space between two minor graduation lines when it is rotated once. Four revolutions will move the thimble (and spindle) exactly 0.1 inch.

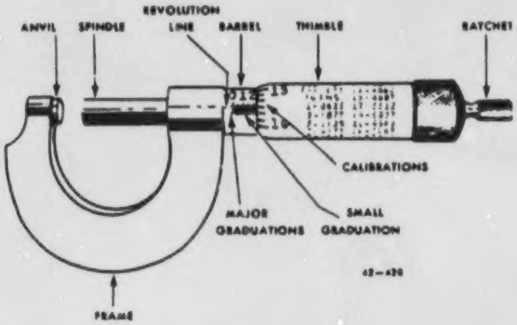


Figure 84. Outside micrometer.

17-5. Around the inner end of the thimble there are 25 equal calibrations, or divisions. Each division represents 0.001 inch, since one revolution moves the thimble 0.025 inch. Usually every fifth division is marked. Thus, the numbers 0, 5, 10, 20 are found on the tapered end of the thimble, and these numbers are used in computing the dimension of an object.

17-6. The number located on the tapered end of the thimble and aligned with the revolution line indicates the number of thousandths the thimble has moved past the last smaller graduation on the barrel.

17-7. Refer to figure 85 and let's assume that the dimension reading is taken on a 0 to 1 micrometer. The thimble is positioned so that the second major graduation on the barrel is fully uncovered. Observe that the scale indicates a reading of 0.200 inch. One smaller graduation on the barrel is completely uncovered. We will add the quivalent of this graduation, bringing the measurement up to 0.225 inch. You will notice that the 12th graduation on the thimble is aligned with the revolution line. Therefore, 0.012 inch is added to give a total measurement of 0.237 inch. The same reading found on a 4-inch micrometer would indicate a dimension of 3.237. This is because the range of this micrometer is between 3 and 4 inches. Thus, we find that we have one extra step to follow when using an outside micrometer to measure anything greater than an inch. That step consists of adding the least possible measurement, shown on the frame, to the reading from the micrometer scale.

17-8. One of the greatest abuses of this type of micrometer is overtightening (turning the thimble too hard against the work). Use just enough pressure to bring the anvil and spindle against the surface of the object being measured. A light pressure supplied by thumb and forefinger is enough. The micrometer should never be tightened enough to support its own weight. On many micrometers a ratchet is built into the end of the thimble, as shown in figure 84. The ratchet is preset to slip if too much pressure is applied to it. Therefore, turn the thimble with the ratchet and you will safeguard the tool and its accuracy. Many micrometers have a lock identified by a knurled ring in the frame around the spindle. When the lock is applied, more pressure is required to turn the thimble. The lock is used to secure the thimble after it has been positioned; thus, this lock enables to the tool to be handled without disturbing the reading.

17-9. **Outside Micrometer with Vernier Scale.** Any micrometer that can be read to one-ten-thousandth of an inch has an additional scale. It is called the vernier scale. With the use of a vernier, it is possible to divide the thimble calibrations into 10 equal parts, resulting in a reading in increments of one ten-thousandths of an inch. The vernier scale consists of 10 equally spaced, numbered lines which extend lengthwise along the barrel. They are parallel to the revolution line, as shown in figure 86. These lines occupy the same amount of space as nine lines on the thimble. The effect of this 10-part vernier is to split the thousandths into one ten-thousandths. When reading the vernier scale, tends through the center of the thimble and barrel and protrudes from the hole in the center of the base. The base provides a reference sur-

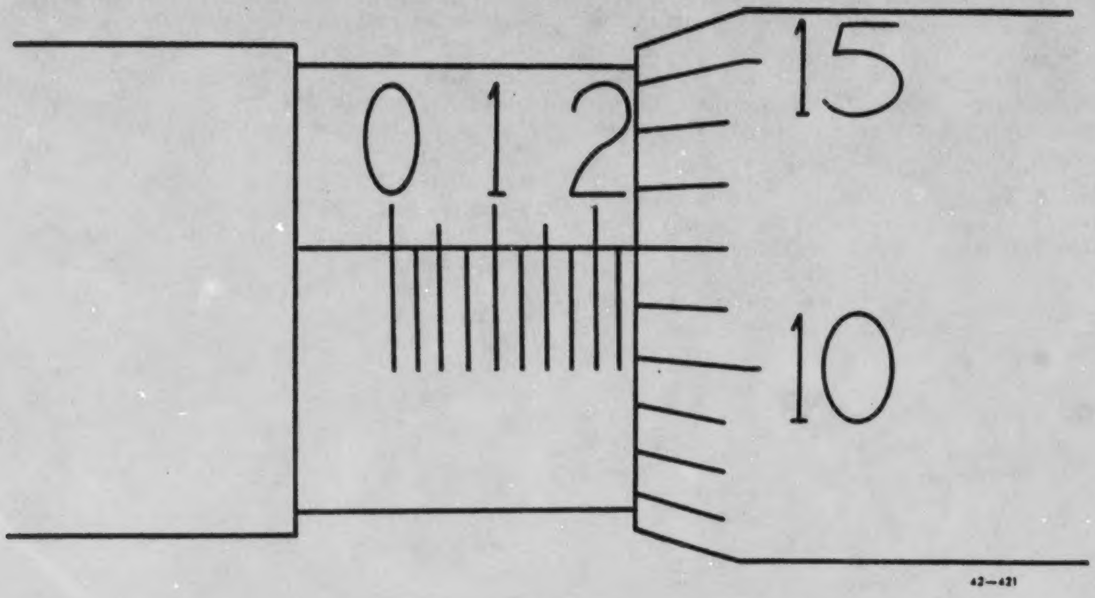

0
1
2
15
10
42—421

Figure 85. Reading outside micrometer (0.237 in).

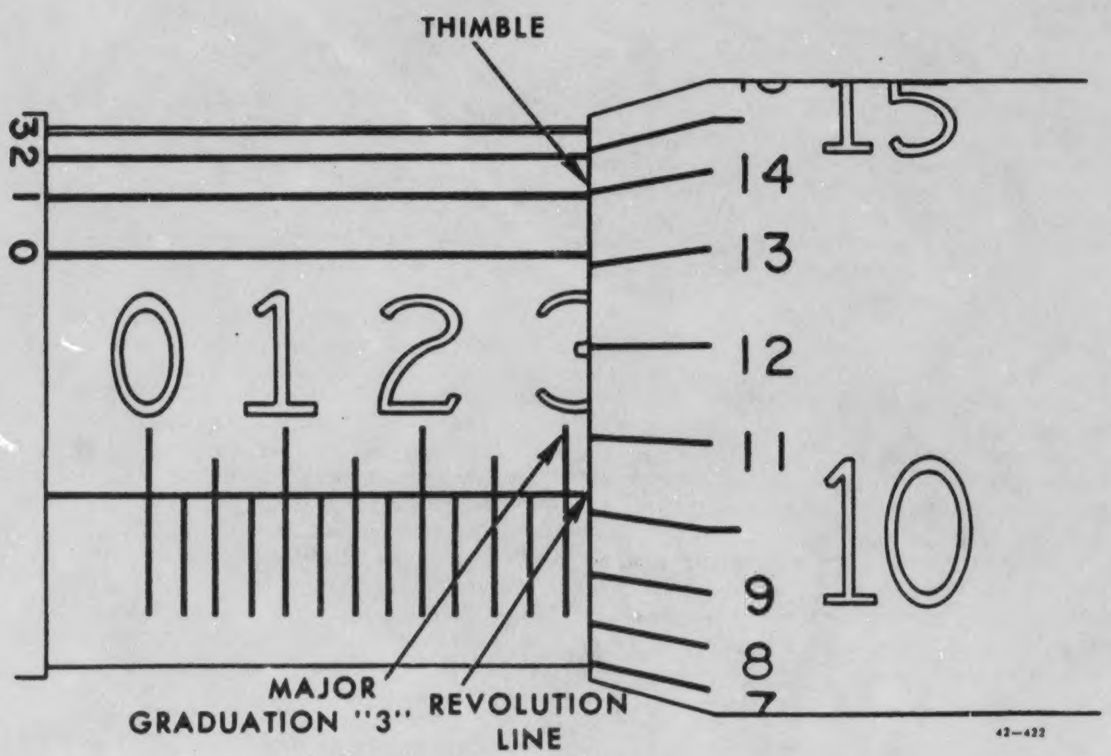

THIMBLE
3
2
1
0
0
1
2
3
15
14
13
12
11
10
9
8
7
MAJOR GRADUATION "3"
REVOLUTION LINE
42—422

Figure 86. Reading outside micrometer with vernier scale (0.3101 inch).

use the number on the scale which is most closely aligned with any calibration on the thimble. As an example, consider a reading on a 0- to 1-inch micrometer (fig. 86). In the illustration the major graduation 3 is uncovered. This indicates that the surfaces being measured are at least 0.300 inch apart. Since no minor graduations after the 3 are uncovered, no units are added from the barrel. Instead, read from the thimble calibration. There you find that the tenth graduation is the last one to pass the revolution line. Add 0.010 inch for the thimble reading to obtain a total reading of 0.310 inch. Now read the vernier scale. There you find that the No. 1 graduation of the vernier (on the barrel) is most closely aligned with a calibration on the thimble. This final figure, 0.0001 inch, is added to those already determined. You now have the total measurement of 0.3101 inch.

17-10. Whenever you read a micrometer scale of this type, remember to read only those major graduations fully uncovered. Then go to the next finer scale to determine the value of the "partly used" graduations. In the above example, a bit of the major scale is uncovered, which showed that the dimension was greater that 0.300 inch. The next finer scale shows that the measurements have increased 10 full thousandths beyond the 0.300-inch mark. Also, the movement is slightly beyond the 0.010-inch mark on the thimble; therefore, you must look at the vernier to determine the exact amount.

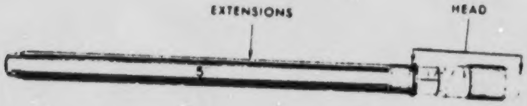


Figure 87. Inside micrometer.

17-11. Besides not applying much pressure to the thimble, remember to handle these tools with care. When not in use, they should be kept clean; and, if practicable, coat them with light oil to prevent corrosion. Do not close the gap between the anvil and spindle tightly when storing a micrometer. This tension may destroy its future accuracy.

17-12. **Inside Micrometer.** The inside micrometer, shown in figure 87, can be used to measure the inside dimension (I.D.) of an opening in an object. The inside micrometer measures just as precisely as does an outside micrometer. However, the nomenclature differs slightly from that of the other micrometers. Also, the range of an inside micrometer is usually only 0.500 inch. The head (fig. 87) of the inside micrometer contains the barrel and the thimble as we know them in the outside micrometer. Fully closed, the inside micrometer measures 1.5 inches. Hence, with this micrometer we cannot measure any bore less than 1.5 inches in diameter. By adding an extension of a given length (extensions are marked as to added value), the tool can be adjusted to measure greater dimensions. A 5-inch extension is shown in figure 87. The maximum measurement is governed by the size of the extension available. The longest single extension in most sets is 6 inches long. Extensions can be added to one or both ends of the head on many of these tools. As a result it is possible to increase the maximum measurement. The tool shown in figure 87 accommodates an extension at one end of the head only.

17-13. The procedure for reading this tool is quite like that for reading the outside micrometer. The reading is taken from the head in exactly the same manner as before. Add the scale reading to 1.5 inches (head value, if closed) and to the value of the extension used (if any). This gives you the total of the dimension; that is, scale reading +1.5 inches (head value, closed) + extensions = total inside dimension. Study figure 88 for a sample reading with a 5-inch extension installed. From the scale you get a reading of 0.243 inch. To this add the head minimum length of 1.5 inches, giving a total head length of 1.743 inches. Finally, add the value of the extension, 5 inches. This gives a total measurement of 6.743 inches (0.243 inches + 1.5 inches + 5 inches = 6.743 inches).

17-14. Removable caps are installed on the ends of the head to enable installation of an extension. Caps are also provided on the extensions to adjust the length of the extension if needed. The cap on an extension must not be removed when you use the tool; adjustment is made when the tool is checked by authorized personnel. When installed, caps or extensions should be screwed in snugly but not excessively. Once again, the pressure of the thumb and forefinger is enough to get accuracy without damaging the tool.

17-15. **Depth Micrometer.** The depth micrometer, shown in figure 89, is used to measure the depth of a hole. The range of most depth micrometers is 1 inch. Extension rods are used to extend the range from readings of 0 to 1 inch, 1 to 2 inches, or 2 to 3 inches. These extension rods are fitted into the thimble by removing the thimble cap. Then insert the extension rod, and replace the thimble cap to hold the rod in place. The extension rod ex-

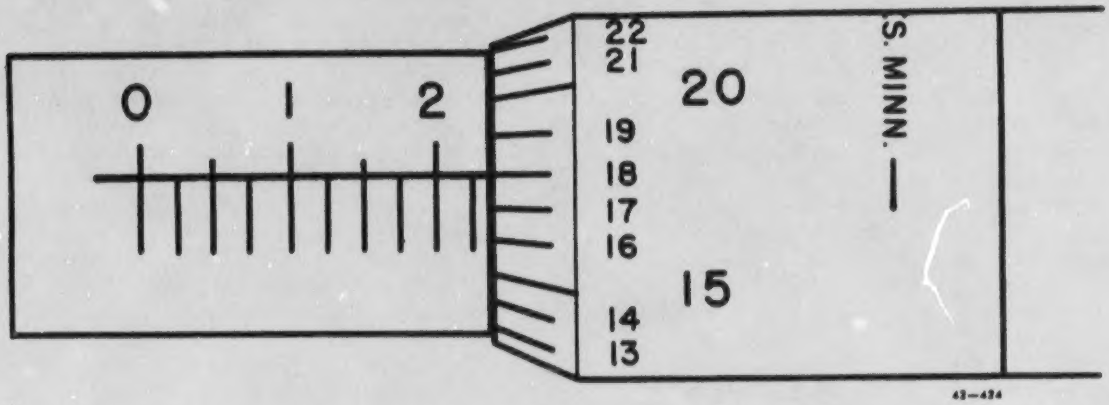


Figure 88. Reading inside micrometer (0.243 inch).

face in the same manner as the anvil in the outside micrometer. The extension rod end serves as the other surface just as the spindle does in the outside micrometer. Hence, we measure the distance between the plane (level) of the base and the end of the extension rod. With the 0- to 1-inch extension rod installed and the thimble turned to the 0.000 position, the tip of the rod will be flush (even) with the flat reference surface of the base. If the 1- to 2-inch rod were installed, the rod would extend exactly 1 inch out of the base. The extension rod is extended or retracted by turning the thimble.

17-16. Whenever an extension rod is used, a measurement reading must include the value of its length. The scale on this type of micrometer is inverted as compared with the outside micrometer. The 0.000 position on the outside micrometer is found with the thimble covering the barrel to the "0" mark. With the depth micrometer the barrel scale is completely exposed when the tool is reading 0.000. Although the scale on the barrel is inverted, it is otherwise identical to the scales already discussed. A typical reading of 1.585 inches is shown in figure 90. A 1- to 2-inch extension rod is installed in the tool so that the first measurement available is 1 inch. Number 6 is the lowest visible number of the major graduations; the next number to be read must lie between 5 and 6. The partial dimension reading now totals 1.500 inches. Three minor graduations on the barrel are completely covered. This brings the total reading to 1.575 inches. The reading on the thimble (0.010) is added directly to the figure computed to this point. Now this brings the complete reading to 1.585 inches.

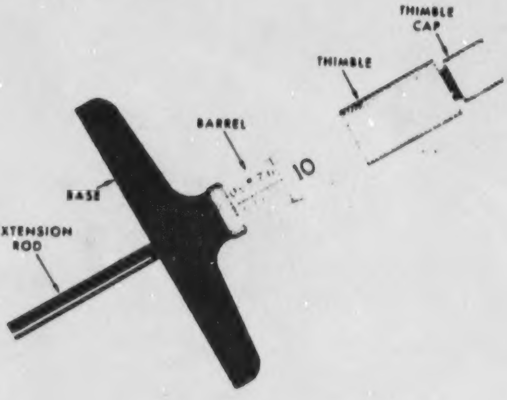


Figure 89. Depth micrometer.

17-17. The above reading can be obtained by a slightly different method. Again refer to figure 90. The procedure involves the addition of the value of the extension rod (1.000 inch) to the lowest visible numbered graduation on the barrel (0.600-inch). Then subtract the minor graduations (0.000-inch), plus the amount the thimble was short of a complete revolution (0.015-inch). Thus, 1.600 inches less 0.015 inch gives a reading of 1.585 inches. This is the same reading obtained by the other method of reading the depth micrometer.

17-18. Special measuring tools, such as micrometers, are used to make precision measurements. Needless to say, they must be treated with care. Merely dropping a micrometer can affect its accuracy and make it useless. Other handtools, although not as delicate as micrometers, also must be treated with care, such as keeping them clean, oiled, and properly stored. It is often said, "A mechanic is only as good as his tools." Only by having good tools and using them for their intended purpose can you do quality maintenance.

18. Metals and Corrosion Control

18-1. Corrosion control and treatment are of major importance to all aircraft pneudraulic systems mechanics. Corrosion reduces the effectiveness of the aircraft weapon system. Corrosion is costly, because it shortens the useful life of equipment.

18-2. Scheduled inspections are essential for early detection and correction of corrosion. Preventive maintenance lessens the total amount of labor used and expense required in corrosion control. Preventive maintenance will insure that corrosion does not keep a system from doing its job.

18-3. Most metals are subject to corrosion. However, corrosion can be lessened by the use of corrosion-resistant protective finishes. Although your equipment has a protective coating, accumulated soil, salts, industrial fumes, and moisture will cause this coating to break down. This allows corrosion to set in.

18-4. **Corrosion.** Corrosion can be defined as the deterioration of a metal by reaction to its environment. Corrosion occurs because of the tendency of most metals to return to their natural state. An example of this is iron in the presence of moist air. The iron will revert to its natural state: iron oxide or rust. Metals corrode (oxidize) by the direct chemical or electrochemical reaction with their environment.

18-5. Refer to figure 91 to better understand the causes of the most common type of corrosion. Let's consider what happens in electro-chemical reaction (corrosion). *It can be likened to the action that takes place in a tiny battery cell.* Four conditions must exist before electro-chemical corrosion can occur:

- There must be a metal that corrodes and acts as the anode.
- There must be a less corrodible metal that acts as the cathode.
- There must be a continuous liquid path between the two metals, which acts as the electrolyte. This is usually condensate and salt or other contaminations.
- There must be a conductor to carry the flow of electrons from the cathode to the anode. This conductor is usually in a form that provides for metal-to-metal contact (rivets, bolts, welds, etc.).

18-6. The elimination of any one of the four conditions will automatically stop corrosion. As an example, you can apply an organic film (paint, oil, grease, plastic, etc.) to the surface of the metal. This prevents the electrolyte from connecting the cathode to the anode, and the current cannot flow; therefore, no corrosion can occur.

18-7. At normal atmospheric temperatures, metals do not corrode much without moisture; but, moisture in the air is usually enough to start action. Oxygen is also usually needed for corrosion to take place with moisture at room temperature. Some of the other factors that affect a metal's tendency to corrode are as follows:

- Acidity or alkalinity of the electrolytic moisture.
- Stability of the corrosion products.

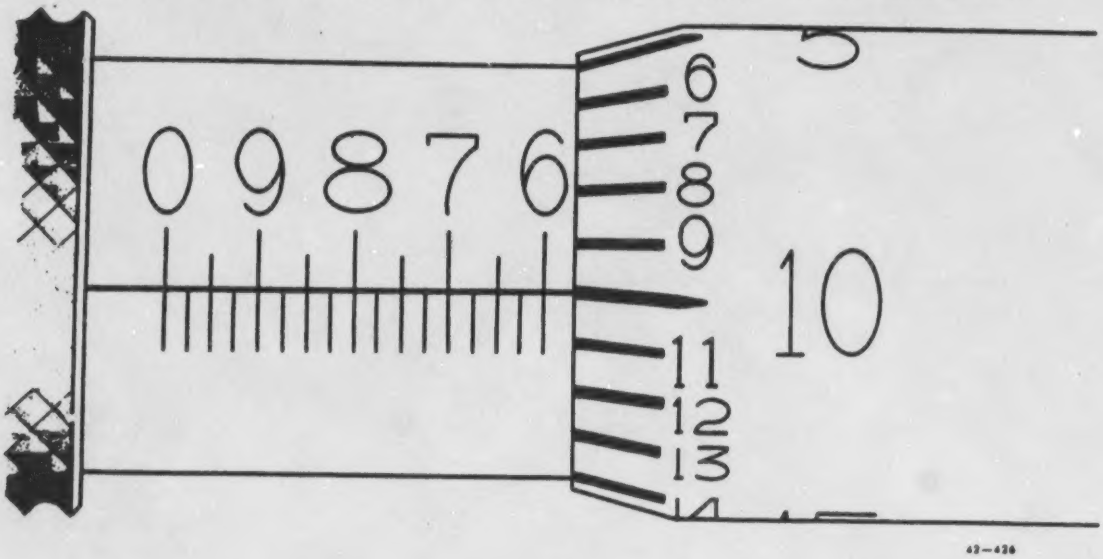


Figure 90. Reading a depth micrometer (1.585 inches).

- Biological organisms, particularly anerobic (can live without air) bacteria.
- Variation in composition of the corrodible metal.
- Temperatures.

18-8. The initial rate of corrosion is usually quite high and then it slows down. This is because the oxide film that forms on a metal surface tends to protect the metal underneath. The oxide is an end product of corrosion and has little tendency to change. Therefore, it is more stable than the metal underneath and shields it somewhat.

18-9. When items made of different metals must perform under varied climatic conditions, corrosion becomes a problem. The presence of salts on metal surfaces (from sea coast operations, for example) greatly increases the electrical conductivity of any moisture present. This speeds up corrosion.

18-10. Moisture tends to collect on dirt particles. Keeping surfaces clean on passive (less corrodible) metal or alloy components is of great importance. It is often more important than on plain carbon steel or copper base alloy ones. Some metals are relatively passive by nature. More active ones can be made passive by chemical treatment as by coating with a rust inhibitor. Others develop passiveness because of environmental conditions. For instance, aluminum develops a protective film of aluminum oxide. Sometimes large surfaces of a passive metal contain small specks of a more active metal or spots where the passiveness was less complete. These points can easily become anodes with the large passive areas the cathode. They, then, become the focal points for corrosion in the presence of oxygen and moisture, and pitting is the result.

18-11. A similar action takes place in crevices formed between surfaces of identical passive metal. Examples of such crevices are at lap joints, around rivets, bolts, and screws, at threaded connections, or around spot welds. Because of small areas the concentration of oxygen is less in these crevices and cracks. This results in a more active condition in the crevice known as an oxygen cell. As a result, in the presence of moisture, these crevices become highly susceptible to accelerated corrosion. This is especially true if the moisture is contaminated. For these reasons, cleanliness must be maintained and corrosion preventive measures observed even on corrosion resistant metals.

18-12. So far we have discussed electrochemical corrosion that occurs between metals of unlike chemical activity. We also discussed where it occurs in areas of unlike chemical activity (dry and wet) on a single metal. In the last sentence of paragraph 18-4, results of a direct chemical reaction on a metal. Basically, it can be said the two processes are essentially the same. The main difference is that in the case of electrochemical corrosion, the anode and cathode reactions take place at the same point. An example of direct corrosion is the action of an acid on metal.

18-13. Some areas of our systems are sub-

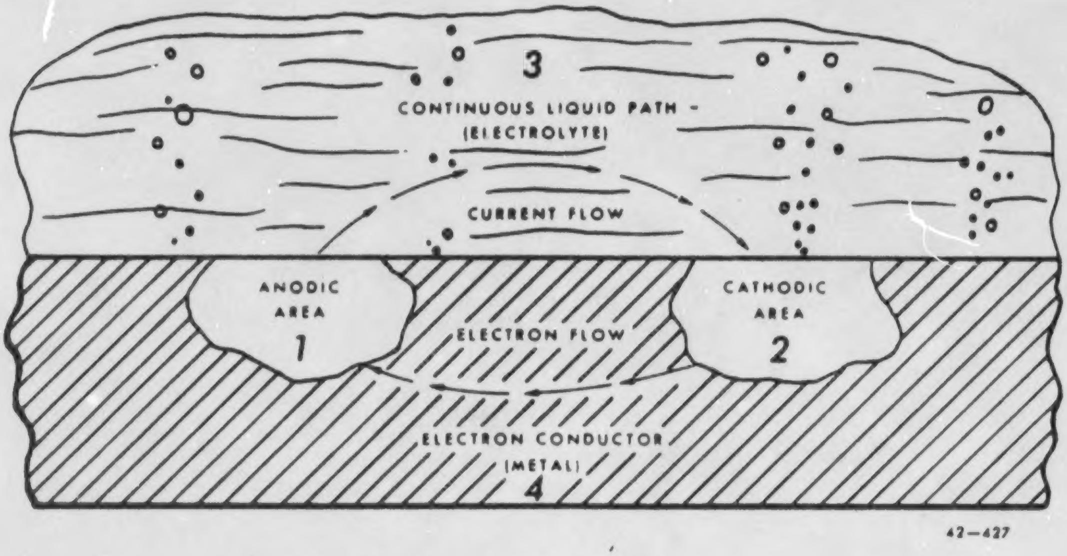


Figure 91. Condition for electrochemical corrosion.

jected to more corrosive substances than others; the possibility of corrosion varies accordingly. Also, because of these varying conditions, the necessary control measures will vary. Nearly all corrosive attacks start on the surface of metal exposed to corrosive conditions. If allowed to progress, corrosion works down into the core of the material. Since corrosion never starts in the core, there is always evidence on the surface when an attack is in progress.

18-14. Corrosion has been cataloged and typed in many ways. For descriptive purposes, let us discuss it under the most commonly accepted titles.

18-15. *Uniform etch corrosion.* The surface effect produced by most direct chemical attacks (as by an acid) is a uniform etching of the metal. On a polished surface this type of corrosion is first seen as a general dulling of the surface. If such corrosion is allowed to continue, the surface becomes rough and, possibly, frosted in appearance.

18-16. *Pitting corrosion.* The most common effect of corrosion on aluminum and magnesium alloy parts is called pitting. It is first noticeable as a white or gray powdery deposit, similar to dust, which blotches the surface. When the deposit is cleaned away, tiny pits or holes can be seen in the surface. Pitting corrosion may also occur in other types of metal *alloys.*

18-17. *Intergranular corrosion.* This corrosion attacks the grain boundaries of a material. A highly magnified cross-section of any commercial *alloy* shows the granular structure of the metal. This structure consists of quantities of individual grains. Each of these tiny grains has a clearly defined boundary that differs chemically from the metal within the grain center. The adjacent grains of different elements can react with each other as anode and cathode when in contact with an electrolyte. This conductive arrangement causes corrosion at the grain boundary. Such corrosion destroys the solidity of the material.

18-18. *Exfoliation corrosion.* Exfoliation is a form of intergranular corrosion. The surface becomes flaky. It shows itself by "lifting up" the surface grains of a metal by the force of expanding corrosion occurring at the grain boundaries just below the surface. This sometimes looks like paint blisters on a freshly painted surface. This is firm visible evidence of intergranular corrosion. This type of corrosion is most often seen on extruded sections. There the grain thicknesses are usually less than in rolled alloy form. Most of this type of corrosion is found on aluminum alloy ducting.

18-19. *Galvanic corrosion.* Galvanic corrosion occurs when dissimilar metals are in contact. The contacting of these unlike metals provides an external circuit by the presence of a buildup of corrosion between these metals; for example, when aluminum components are attached with steel bolts or screws.

18-20. *Concentration cell corrosion.* Concentration cell corrosion occurs when two or more areas of a single metal surface are in contact with *different concentrations* of the *same solution*: moist air, water, chemicals, etc. The three general types of concentration cell corrosion are metal ion concentration cells, oxygen concentration cells, and active-passive cells. TO 1 – 1 – 2, *Corrosion Control and Treatment for Aerospace Equipment*, gives a detailed explanation of these types.

18-21. *Stress corrosion cracking.* This corrosion is caused by the simultaneous effects of tensile stress and corrosion. Stress may be internal or applied. Internal stresses are produced by nonuniform shaping during cold working of the metal. These stresses are also created by press and shrink fitting general hardware. Stresses induced when a piece is deformed and stresses in rivets and bolts are internal stress. These items can crack because of internal stresses and are aggravated by corrosion. This cracking is called stress corrosion cracking.

18-22. *Fatigue corrosion.* Fatigue corrosion is a special case of stress corrosion caused by the combined effects of cyclic stress and corrosion. An example of this kind of corrosion is unprotected engine bleed air ducts that are exposed to moisture. They are held in such a way that thermal expansion causes repeated twisting of the duct. This creates metal fatigue or crystallization cracks in which corrosion starts.

18-23. **Corrosion Inspection.** Without proper and systematically performed inspections and maintenance, corrosion will seriously damage your systems and equipment. All equipment should be carefully inspected at each periodic inspection for signs of corrosion.

18-24. Typical locations that should be closely inspected are as follows:

a. Unpainted aluminum duct and component areas.
b. Component and duct direct mating seams.
c. Areas where moisture does not evaporate as rapidly as areas exposed to direct sunlight and air.
d. Drain holes that may be clogged (water separator drain, etc.).
e. Components and ducts underneath floorboards.
f. Fittings, braces, and compound parts inside the aircraft where foreign matter or

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moisture may gather because of improper drainage outlets.

g. Areas where dissimilar metals are in contact (including bolts, nuts, washers, and screws).

h. Component or duct spotwelds.

i. Hinges.

j. Exhaust gas paths (heater exhausts).

The above are but a few inspection areas that should be checked closely.

18-25. **Corrosion Removal and Treatment.** Part of your assigned duties may be to inspect your systems or equipment for corrosion. If you find corrosion in any area, removing the corrosion and applying preventives are "musts."

18-26. You may or may not be involved in corrosion removal and treatment. It depends on the directives and SOPs of your assigned base and unit. At present the Air Force has corrosion control specialists; but, since this AFSC is relatively new, some bases may not have these specialists. If this is the case, you will be called upon to handle your own system, component, and general equipment corrosion problems.

18-27. When you need information on treatment of corrosion, refer to TO 1–1–2, *Corrosion Control and Treatment for Aerospace Equipment*. This technical order contains detailed information on corrosion removal procedures. It also tells how to apply corrosion preventives for the various types of metals used in aircraft. Methods, materials, and equipment used in preventive maintenance painting are also discussed.

18-28. Inspections may show corrosion so severe that it requires the removal of the damaged component or part. For this, use the repair procedures as outlined in the specific–3 technical order for the aircraft.

66

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WORKBOOK

Pneudraulic Functions and Career Program

SELF-TEACHING AIDS
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This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Study Reference Guide, the Chapter Review Exercises and their answers, and the Volume Review Exercise. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet. If you will follow the study plan given in "Your Key to Career Development," which is in your course packet, you will be leading yourself by easily learned steps to mastery of your text.

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Keep the rest of this workbook in your files. Do not return any other part of it to ECI.

EXTENSION COURSE INSTITUTE
Air University

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Volume Review Exercise

ECI Form No. 17

STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate the numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Numbers 100 through 115

Guide Number	
100	Introduction to Air Force Organization and Career Program; Organization of the Air Force; Organization of Maintenance Activities; pages 1–3
101	Air Force Career Program; pages 3–7
102	Introduction to Air Force Publications; Types of Air Force Publication; pages 8–12
103	Air Force Technical Order System; pages 12-28
104	Introduction to Supply Management and Security; Responsibility for Public Property; pages 29–36
105	Principles of Supply Authorization and Management; Security System; pages 36–39
106	Introduction to Good Housekeeping and Safety Practices; Good Housekeeping; pages 40–41
107	Safety Practices; pages 41–48
108	Introduction to Hydraulic Fluids and Plumbing Materials; Fluids; pages 49–53
109	Seals and Backup Rings; pages 53–57
110	Fittings; pages 57–63
111	Pneudraulic Hose; Safetying Devices; pages 63–73
112	Introduction to Maintenance Tools; Handtools: Screwdrivers; Hammers; Wrenches; pages 74–79
113	Handtools: Files; Hacksaws; pages 79–82
114	Special Measuring Tools; pages 82–87
115	Metals and Corrosion Control; pages 87–90

MODIFICATIONS

Pages 2- 6 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 4

Objective: To show a knowledge of good housekeeping, fire prevention, and safety practices.

1. What causes most accidents? (Intro.-1–3; Fig. 19)

2. What is the first rule of good housekeeping? Why? (9-2)

3. List the classes of fires and give one or more examples of each. (9-14; Fig. 20)

4. What colors are used for safety markings? (10-3)

5. What protection is provided for use against high-intensity sound? (10-11)

6. What should every mechanic know about egress systems? (10-16--18; Fig. 21)

7. List the potential danger areas involved in working around jet aircraft. (10-5,19)

8. Before performing maintenance on power-actuated flight controls or bomb doors, what should be done? (10-19)

9. Is it permissible to service an accumulator with oxygen? Explain. (10-23)

10. What must you wear while working in or around radioactive materials? (10-25, *c,d*)

11. Why is off-duty activity considered more hazardous than a man's work area? (10-28,29)

12. Which of the off-duty activities is considered to be the greatest threat? (10-30)

13. What form is used for reporting a ground accident? (10-40)

CHAPTER 5

Objective: To demonstrate knowledge of the use of hydraulic fluids, seals, and fittings, and of manufacturing pneudraulic hose and safetying components.

1. What type of fluid must be used with synthetic rubber seals? (11-3)

2. Explain how various types of fluid can be distinguished from each other. (11-3,5,10)

3. If a cleaning solvent is not specified, what would be used on a unit in a petroleum base system? (11-17)

4. What is meant by fluid contamination? (11-19)

5. Explain the difference between a packing and a gasket. (12-1)

6. Explain how you will find the part number of a seal for a unit you are repairing when no technical order is available. (12-5)

7. How are AN6290 or MS28778 gaskets identified? (12-9)

8. Explain the difference between AN6227 packings and MS28775 packings. (12-17,18,19)

9. Explain why MS flareless tube assemblies resist vibration loosening effects better than AN tube assemblies. (13-9)

10. Explain the procedure for torquing MS flareless nuts. (13-16)

11. When installing a universal fitting into a boss, what is the minimum and maximum number of turns permitted with the fitting after the gasket is firmly against the boss? (13-19)

12. Explain the purpose of the yellow lettering on MIL–H–8794 and MIL–H–8788 hose. (14-5,6)

13. What are the advantages of using Teflon hose? (14-9)

14. What is the purpose of the clearance between the B nut and the socket on medium-pressure hose assemblies? (14-13)

15. Why are the nipple and inside of the hose lubricated? (14-13)

16. Why are the installation date and the date of hose manufacture etched on the sockets? (14-15)

17. Why should Teflon hose be wrapped with masking tape before cutting? (14-18)

18. Why is it important that you do not turn the hose an excessive amount in the high-pressure socket? (14-24)

19. Explain how the clearance is maintained between the B nut and the hex of the nipple on the high-pressure hose end fitting. (14-24)

20. What is the time limitation for using rubber hose assemblies for airborne equipment? (14-30)

21. In addition to using the correct size, what other very important rule should always be observed when safetying unit with cotter pins? (15-3)

22. When you use safety wire, how should the wire be arranged between a part and the anchorage point? (15-8)

CHAPTER 6

Objective: To demonstrate knowledge of the selection and use of common handtools and special measuring tools.

1. What is the primary difference between a common screwdriver and a Phillips screwdriver? (16-3; Fig. 71)

2. Name three tools that a screwdriver is not supposed to replace. (16-4)

3. How are hammers classified? (16-6)

4. What precautions should you take when using a hammer on a machined or polished surface? (16-8)

5. How are the sizes of pliers classified? (16-10)

6 How are the sizes of open-end wrenches determined? (16-16)

7. What is the best feature about box-end wrenches? (16-22)

8. What is the intended purpose of a crescent wrench? (16-26)

9. What is the advantage of a 6-point socket over a 12-point socket? (16-31)

10. In which direction should you pull a breakaway type torque wrench? (16-35)

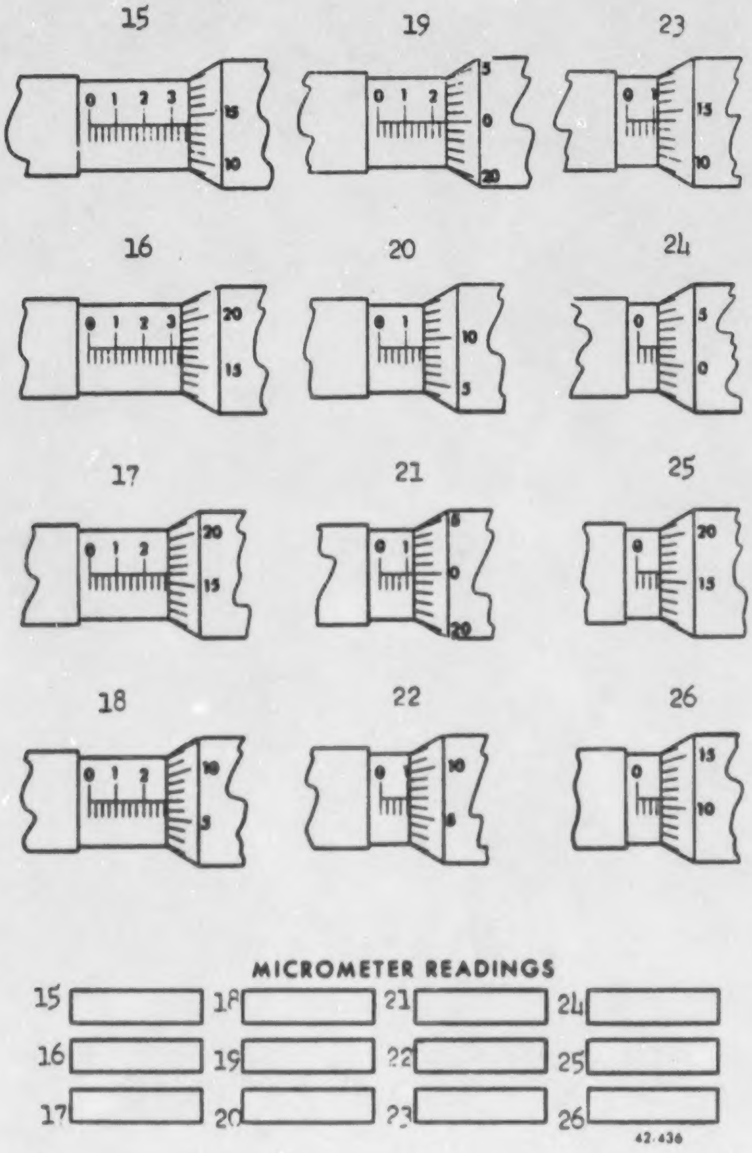
11. Why are Allen wrenches L-shaped? (16-38)

12. What should flexible hacksaw blades be used to cut? (16-46)

13. What is the value in thousandths of an inch of the numbered increments on the barrel of a micrometer? (17-4)

14. What is the smallest increment on a micrometer that has no vernier scale? (17-5)

For questions 15 through 26, refer to CRE figure 1 and read the micrometers illustrated; place your answer in the spaces provided at the bottom of the figure. (17-4,6)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MICROMETER READINGS
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CRE Figure 1. Reading a micrometer.

27. In corrosion control, what two major items are essential to prevent excessive material and labor costs? (18-2)

28. Briefly define corrosion. (18-4)

29. Describe briefly what conditions must exist for electrochemical corrosion to set in. (18-5)

30. How can corrosion be stopped or prevented? (18-6)

31. Describe briefly at what point during the corrosion process that the rate of corrosion is the greatest. (18-8)

32. Describe briefly where corrosion first starts. (18-13)

33. Describe the surface appearance of a metal with uniform etch corrosion. (18-15)

34. Describe briefly the appearance of pitting corrosion on nontreated aluminum alloy parts. (18-16)

35. Describe briefly the activity of intergranular corrosion in an alloy. (18-17)

36. Describe briefly the physical characteristics of exfoliation corrosion. (18-18)

37. Describe how concentration cell corrosion develops. (18-20)

38. Describe briefly what causes stress corrosion. (18-21)

39. What causes fatigue corrosion? (18-22)

40. Describe briefly what specific measures you can perform to reduce the effect of corrosion. (18-23)

41. During an aircraft corrosion inspection you found a component beyond repair. What procedures must you follow? (18-28)

CHAPTER 4

1. Unsafe acts of people; thoughtlessness.

2. Personal cleanliness. This is true because a person who keeps himself clean has developed a habit which will very likely be carried over into all his actions.

3. Class A - wood, paper, trash, Class B - gasoline, oil, paint. Class C - electrical.

4. Red - danger or emergency stop devices; yellow - caution; green - safety equipment facilities; black and white - information.

5. Ear defenders (earplugs). You can also wear a protective helmet or headset over the earplugs for added protection.

6. Every mechanic should know where the egress system safety pins are installed and the correct method of installation. Any time you work in these areas, make sure the safety pins are installed and that you don't disturb them.

7. (1) Engine intake suction; (2) engine exhaust; (3) turbine wheel rotation; (4) high-intensity sound; (5) radiofrequency radiation; (6) armed aircraft; (7) egress systems, seat and canopy; (8) power-actuated equipment, flight controls, bomb doors, etc.

8. Make sure that you have disabled the system, such as pulling the circuit breaker and tagging the control DO NOT OPERATE; installed safety locks; and depleted system pressure.

9. No. Oxygen mixed with grease, oil, or flammable gases creates a highly explosive mixture.

10. Protective clothing and a film badge and/or a pocket dosimeter.

11. Off duty is more hazardous than on duty because you are made aware of the dangers involved in your job. When on duty you are also under almost constant supervision and prepare yourself for the job. Off duty has many unseen dangers and no one to remind you of safety practices.

12. Driving an automobile is the greatest threat to life and limb.

13. USAF Form 711 and 711a. Ground Accident/Incident Report.

CHAPTER 5

1. Petroleum-base fluid requires the use of synthetic rubber, leather, or metal composition seals.

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2. Petroleum-base fluid is red, vegetable-base fluid is blue, and synthetic-base fluid is a golden-amber color.

3. PS–661.

4. Fluid contamination means that the system contains something other than the hydraulic fluid normally used, such as improper fluid, water, metal, and dust.

5. A packing is used as a seal between two moving parts, whereas a gasket acts as a seal between two stationary parts.

6. You could measure the old seal I.D. and width then look it up in the applicable specification to obtain the dash number.

7. They have a blue stripe around the outside circumference.

8. The AN6227 packing has two or more dots and is used in the temperature range of -65° F. to 160° F. The MS28775 packing has one blue dot, and its temperature range is -65° F. to 275° F.

9. The flareless tube assemblies resist vibration loosening effects better because of the spring washer effect (bowed condition) of the MS flareless sleeve.

10. Turn the nut with your fingers until a sharp rise in torque is noted. Then, using a wrench, tighten 1/16 to 1/3 turn more.

11. 1½ turns minimum; 2½ turns maximum.

12. The lettering gives the specification number, size, quarter and year of manufacture, plus the 5-digit manufacturer's code number. In addition, the yellow lettering indicates the natural lay of the hose.

13. Teflon hose has a practically unlimited storage time, greater operating temperature range, and it can be used in more systems.

14. The clearance is required to allow the nut to swivel freely.

15. To allow the nipple to slide into the inner tube and prevent cutting or bulging as it goes in.

16. These provide a positive date for replacement.

17. To prevent a flare-out or separation of the wire braid.

18. Because this will grind away material from the buttresses inside the socket.

19. The wire retainer maintains the clearance between the B nut and nipple hex.

20. The time limitation is 16 quarters (4 years) calculated from the date of manufacture stenciled on the hose.

21. Never reuse a cotter pin.

22. It should oppose any loosening of the part.

CHAPTER 6

1. The common screwdriver has a straight point, whereas the Phillips screwdriver has a cross point.
2. Chisel, pry bar, and punch.
3. They are classified according to the weight of the head without the handle.
4. Always protect the surfaces with a piece of soft brass, copper, lead, or hardwood.
5. According to the length of the handles.
6. By measuring the openings between the jaws.
7. They can be used in close quarters.
8. It is primarily used when an odd-size nut or bolt is encountered. It is not intended to take the place of standard open-end, box-end, or socket wrenches.
9. The 6-point socket holds the nut better, allowing less wear because of a better holding surface.
10. Always pull the wrench in a clockwise direction, with a smooth and steady motion.
11. Allen wrenches are L-shaped to permit their use for a long or short distance.
12. A flexible hacksaw blade is used for sawing hollow shapes and metals of light cross section.
13. 0.100 inch.
14. 0.001 inch.
15. 0.364 inch.
16. 0.342 inch.
17. 0.291 inch.
18. 0.282 inch.
19. 0.250 inch.
20. 0.159 inch.
21. 0.125 inch.
22. 0.107 inch.
23. 0.114 inch.
24. 0.077 inch.
25. 0.091 inch.
26. 0.086 inch.

27. In dealing with corrosion, to prevent excessive material and labor costs, it is necessary to establish realistic and timely inspection and preventive maintenance measures.

28. Corrosion is the deterioration of metals by reaction to their environment.

29. Electrochemical corrosion will set in when there is an anode, cathode, electrolyte, and path for the electron flow.

30. Corrosion can be stopped or prevented by eliminating any one of the four conditions that allow it to start or continue.

31. The rate of corrosion is greatest at the beginning.

32. Almost all corrosion starts on the surface.

33. Uniform etch corrosion is always first seen as a general dulling of the metal's surface.

34. Pitting corrosion appears on aluminum parts as spots of white or gray powdery deposits.

35. Intergranular corrosion acts upon the grain boundary between the alloy grains. This form of selective corrosion destroys the solidity of the material.

36. Exfoliation corrosion appears as a lifting up of the metal's surface like paint blisters.

37. Concentration cell corrosion develops when a metal is subjected to two or more different concentrations of corrosive solutions.

38. Tensile stress and corrosion cause stress corrosion.

39. Cyclic stress and corrosion cause fatigue corrosion.

40. Timely and systematically performed inspections and maintenance will greatly reduce the corrosion damage.

41. If a component is found corroded beyond repair, it must be handled as outlined in the aircraft –3 Technical Order.

STOP–

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.

2. USE NUMBER 1 PENCIL.

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VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Use a clean eraser for any answer sheet changes, keeping erasures to a minimum.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

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Multiple Choice

Note: The first three items in this exercise are based on instructions that were included with your course materials. The correctness or incorrectness of your answers to these items will be reflected in your total score. There are no Study Reference Guide subject-area numbers for these first three items.

1. The form number of this VRE must match

   a. my course number.
   b. the number of the Shipping List.
   c. the form number on the answer sheet.
   d. my course volume number.

2. So that the electronic scanner can properly score my answer sheet, I must mark my answers with a

   a. pen with blue ink.
   b. number 1 black lead pencil.
   c. ball point or liquid-lead pen.
   d. pen with black ink.

3. If I tape, staple or mutilate my answer sheet; or if I do not cleanly erase when I make changes on the sheet; or if I write over the numbers and symbols along the top margin of the sheet,

   a. I will receive a new answer sheet.
   b. my answer sheet will be hand-graded.
   c. I will be required to retake the VRE.
   d. my answer sheet will be unscored or scored incorrectly.

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Chapter 4

47. (106) The factor that causes most accidents is

a. ignorance of rules.
b. mechanical failure.
c. hazardous equipment.
d. acts of carelessness.

48. (106) What is the *first* rule of good housekeeping?

a. Clean work area.
b. Good ventilation.
c. Personal cleanliness.
d. Fire prevention system.

49. (106) Prior to performing maintenance on an aircraft,

a. the bomb bay doors must be open.
b. check that static ground wires are properly connected.
c. check that there is power applied to the aircraft.
d. make sure that you know how to get in touch with the base fire department.

50. (106) Refer to figure 20 of the text. Which of the common types of fire extinguishing agents is most harmful to a person's skin or eyes?

a. Foam.
b. Soda acid.
c. Carbon dioxide.
d. Chlorobromomethane.

51. (107) The red band painted around the fuselage and jet engine nacelle on an aircraft indicates the location of the

a. engine exhaust outlet.	c. turbine wheel danger zone.
b. engine air inlet zone.	d. fire access doors.

52. (107) The most common symptom of noise fatigue is

a. a severe rash.	c. sleepiness.
b. extreme elation.	d. emotional irritability.

53. (107) Safety pins for ejection seals are installed

a. immediately after flight.	c. before flight.
b. by egress personnel.	d. with red and blue streamers attached.

54. (107) Before operating power-actuated control surfaces on an aircraft, be sure that the

a. ground safety locks have been removed.
b. system pressure is normal and adequate.
c. areas not being worked on have been properly covered.
d. area is clear of personnel and equipment.

55. (107) It has been estimated that the intestines can be ruptured by what amount of air pressure?

a. 2 psi.	c. 6 psi.
b. 4 psi.	d. 8 psi.

56. (107) For identification of radioactive material, the AFTO 9 series forms are used. They are yellow with a

a. red warning symbol.	c. black warning symbol.
b. blue warning symbol.	d. magneta warning symbol.

57. (107) Before using woodworking machines in a hobby shop, one should particularly seek information about

a. drill press operation.
b. the hobby shop's SOPs.
c. use of wood lathes and associated tools.
d. powersaws, both bench mounted and portable.

58. (107) Supervisors are required to fill out an accident report

a. on disabling injuries or property damage of $25 or more.
b. only on injuries inflicted by AF materials and equipment.
c. within 12 hours after the accident.
d. when injuries result in broken skin no matter how minor.

59. (108) Why is hydraulic fluid MIL–H–5606 dyed red?

a. Adds life to the fluid.
b. For easy identification.
c. To identify the amount spilled.
d. Increases the temperature range of the fluid.

60. (108) When a complete hydraulic system which uses a petroleum-base fluid is prepared for storage, the operator should first drain

a. the system completely and then flush all units with MIL–H–6083.
b. the system completely and then flush the system with MIL–H–3606.
c. the system completely and then flush the system with denatured alcohol.
d. and inspect a sample of fluid from the lowest point in the system.

61. (108) The major disadvantage of synthetic-base fluids is that

a. it must be thinned with a wet nitrogen charge.
b. it deteriorates the seals.
c. its temperature range is very low.
d. it is susceptable to moisture contamination.

62. (108) Some of the more frequent causes of *external* contamination of a hydraulic system are

a. broken lines and normal pump wear.
b. lines uncapped and installing contaminated units.
c. filters being used too long and seals deteriorating.
d. draining unit to drip point and plugging all ports.

63. (109) A typical place where a gasket would be used in a hydraulic system is

a. in valve fittings.
b. on pump drive shafts.
c. in brake assembly pistons.
d. in actuating cylinder pistons.

64. (109) The AN901 standard gasket is normally used with

a. unions.
b. end caps.
c. universal elbows.
d. pipe thread fittings.

65. (109) Which type of Teflon backup ring used in the hydraulic system is shaped like a coil?

a. AN6290.
b. AN6291.
c. MS28782.
d. MS28777.

66. (109) A high operating temperature seal (maximum +275° F.) used in hydraulic and pneumatic systems can best be identified by a

a. blue dot.
b. white dash.
c. blue stripe.
d. white star.

75. (110) When you are installing a universal fitting into a boss and the gasket is firmly against the boss, you should then turn the fitting

a. ½ turn.
b. ¾ turn.
c. 1 turn.
d. 1½ turns.

76. (111) The type of hose that is virtually exempt from storage life limitations is made of

a. Teflon.
b. natural rubber.
c. synthetic rubber.
d. pliable rubber.

77. (111) Common tools needed for assembling medium-pressure hose assemblies by hand include all of the following *except*

a. an oil can.
b. a standard vise.
c. open-end wrenches.
d. an electric needle.

78. (111) According to the text, the first step in fabrication of medium-pressure rubber hose assemblies is to

a. reuse all medium-pressure fittings if serviceable without exception.
b. be sure to reuse all serviceable hose.
c. select the proper size bulk hose.
d. cut the hose squarely and to the required length.

79. (111) During proof pressure testing a medium-pressure hose assembly, a heavy plastic cover is used principally to

a. allow inspection.
b. protect the operator.
c. assure cleanliness.
d. protect the equipment.

80. (111) To provide positive dates for replacement of medium-pressure hose assemblies, the month and year of installation is found.

a. etched on one flat surface of each end-fitting socket.
b. stenciled on the upper end of the assembly.
c. taped on a color-code stripe on the hose assembly.
d. on a tag attached to the assembly.

81. (111) Which of the following hoses does not require mandrels for hand assembly?

a. High-pressure Teflon.
b. Medium-pressure Teflon.
c. Medium-pressure rubber.
d. High-pressure rubber.

82. (111) After the end fittings have been installed, you should blow out the inside of the Teflon hose assembly of any foreign matter by using

a. medium pressure on a water hose.
b. a solution of trichloroethylene.
c. dry, compressed air.
d. a mild soda solution and a soft wire brush.

67. (109) Backup rings are unnecessary in a hydraulic system when the operating pressure does *not* exceed

a. 1500 psi.
b. 1600 psi.
c. 1800 psi.
d. 2000 psi.

68. (109) The maximum storage life of any packing or gasket is

a. 2 years.
b. 3 years.
c. 4 years.
d. 5 years.

69. (110) A blue-colored fitting is usually an

a. AN steel fitting.
b. MS steel fitting.
c. AN aluminum fitting.
d. MS aluminum fitting.

70. (110) The use of antiseize compound on pipe thread fittings should

a. prevent high-pressure leakage.
b. eliminate bimetallic corrosion.
c. be preceded by thread cleaning.
d. reduce the need for frequent inspection.

71. (110) Antiseize thread compound is used on

a. flareless fittings only.
b. pipe thread fittings only.
c. flared tube fittings only.
d. all types of fittings.

72. (110) MS flareless fittings use how many types of nuts and sleeves?

a. Three older types of nuts only.
b. Three new types.
c. Two types only.
d. Any of the four common types.

73. (110) When presetting a flareless fitting assembly, the nut should be slowly screwed onto the tool until the cutting edge of the sleeve grips the tubing sufficiently to prevent rotating the tube with the fingers. The nut should then be tightened an additional

a. 1 full turn.
b. 1 1/6 turns.
c. 1¼ turns.
d. 1½ turns.

74. (110) Overtightening a leaking MS flareless fitting will

a. result in a permanently sealed joint.
b. squeeze out all usable lubricant from the threads.
c. necessitate the use of thread compound for removal.
d. deform the sleeve or tube and cause additional leaks.

83. (111) A special precaution that must be adhered to for cleaning egress hose assemblies when hydraulic fluid has been used for proof test is to

a. flush the hose assemblies at least twice with trichloroethylene.
b. use a strong detergent, flush with clear water, and allow to dry in a warm, closed place.
c. use dry, compressed air only.
d. flush the hose assemblies thoroughly with alcohol and allow fluid to evaporate.

84. (111) When any portion of the metal reinforcement on MIL-H-8794 or MIL-H-8788 hose assemblies is exposed or damaged, the repairman should as a safety precaution

a. replace the hose.
b. replace the outer covers.
c. reenforce the exposed portion with tape.
d. cover the exposed portion with a rubber coating.

85. (111) The maximum number of years synthetic rubber hose used on airborne equipment may be stored is

a. 2.
b. 3.
c. 4.
d. 5.

86. (111) The two most commonly used safety devices on hydraulic units are

a. locknuts and lockrings.
b. safety wire and cotter pins.
c. lockrings and safety wire.
d. cotter pins and locknuts.

Chapter 6

87. (112) One of the most important things to remember when using handtools is

a. the composition or material the tool is made of.
b. to generally use a tool one size larger than needed.
c. to use a substitute tool if it will save time and movement.
d. to use each tool only for its correct purpose.

88. (112) One of the most common hammers used by the Air Force mechanic is

a. a ball peen.
b. a wood mallet.
c. the claw hammer.
d. the brass sledge.

89. (112) Why are the jaws of a wrench usually slightly larger than the size labeled on the jaw?

a. To make the fitting of two size nuts possible.
b. To allow for expansion of the nut as it is tightened.
c. To make it easier to slip the wrench on and off the nut.
d. To prevent overtorquing since the wrench will slip first.

90. (112) One advantage of a 12-point over a 6-point wrench is that

a. it improves the wear capability of the wrench.
b. it allows use of the wrench with a minimum amount of travel.
c. there is little or no chance for the hand to slip off the wrench.
d. this allows more torque to be applied to the nut.

91. (112) The Crescent wrench is primarily intended to be used with

a. standard boltheads and nuts.
b. bolts and nuts requiring additional tightening.
c. hexnuts.
d. odd-sized nuts or bolts.

92. (112) An adjustable jaw Crescent wrench is properly used when

a. the handle is pushed away from you.
b. the handle is pulled away from the jaw.
c. a pipe or extension is added to gain leverage.
d. the pulling force is applied to the stationary jaw side.

93. (112) You would use a torque wrench to

a. hold nuts and hose clamps in place.
b. measure the force of pull when tightening nuts.
c. provide a rapid way of attaching hose clamps.
d. measure the torque produced by a hydraulic motor.

94. (112) How often should a torque wrench be tested?

a. It should be tested quarterly.
b. The wrench should be checked once a year.
c. It should be tested only when it is abused.
d. A torque wrench should be tested every 30 days.

95. (113) Which statement listed below concerning a file would you say is correct?

a. Never drag the file backward.
b. Never oil a file as it will cause it to load.
c. Use a double-cut file when cutting in both directions.
d. Allow the file to load as it causes it to be smoother.

96. (113) Brass stock is best cut with a hacksaw which has

a. a well-tightened, long blade.
b. a flexible blade.
c. an all-hard blade.
d. a fine-tooth blade.

97. (114) The thickness gage is used to

a. measure clearance between objects.
b. measure the thickness of an item.
c. compare threads of nuts and bolts.
d. measure the outside diameter of a tube.

98. (114) When using an outside micrometer,

a. the micrometer should be tightened enough to hold its own weight.
b. each complete revolution of the thimble will move the spindle 0.025 inch.
c. the object to be measured is placed squarely between the face and the spindle.
d. each major graduation on the barrel is equivalent to one revolution of the thimble.

99. (114) Which reading listed below is correct for a micrometer marked "1–2," if you assume that the thimble is positioned so that only the first three graduations to the right of the numeral 1 on the barrel are fully uncovered and that the ninth graduation on the thimble is alined with the revolution line?

a. 0.184 inch.
b. 1.184 inches.
c. 2.184 inches.
d. 3.184 inches.

100. (114) What is one of the greatest abuses in using a micrometer?

a. Overtightening the thimble.
b. Using it to measure outside diameters.
c. Leaving the micrometer with the lock on.
d. Using the ratchet assembly when tightening the spindle.

101. (114) What should we use to measure the depth of a hole?

a. Feeler gage.
b. Thickness gage.
c. Depth micrometer.
d. Inside micrometer.

102. (115) You can generally define corrosion as the

a. breakdown action of the protective finish.
b. direct chemical reaction of a metal to chemicals.
c. deterioration of a metal by reaction to its environment.
d. tendency of a metal to break down in the presence of moisture and salt.

103. (115) It is estimated that the rate of metal corrosion is usually quite high

a. during its final stages.
b. in its beginning stage.
c. from 48 to 72 hours after it sets in.
d. and equally intense during the whole process.

104. (115) Uniform etch corrosion is usually *first* noticed as a

a. slick feel to the metal surface.
b. blistering like that of painted surface.
c. bluish frosting over all the metal surface.
d. general dulling of the metal surface.

105. (115) Which of the following types of corrosion "lifts up" the metal surfaces?

a. Pitting.
b. Galvanic.
c. Exfoliation.
d. Intergranular.

106. (115) Which of the following technical orders covers corrosion control?

a. TO 1-1-2.
b. TO 1-1-4.
c. TO 1-2-1.
d. TO 1-1-12.

107. (115) All metal components of your systems should be inspected for corrosion

a. at every postflight.
b. at each periodic inspection.
c. every 500 flying hours.
d. whenever maintenance is performed.

2-4

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CDC 42152

AIRCRAFT PNEUDRAULIC REPAIRMAN

(AFSC 42152)

Volume 2

Operation and Maintenance of Pneudraulic Components

Extension Course Institute

Air University

Preface

THIS SECOND volume of CDC 42152, *Aircraft Pneudraulic Repairman*, contains six chapters. The first chapter introduces you to basic hydraulic principles, terms, laws, and mechanical advantage. It presents a basic hydraulic system. The next chapter examines components of the power supply section of a hydraulic system. The third chapter discusses pressure-regulating, limiting and controlling devices. In the fourth chapter, you will learn about flow control and flow directing units. Landing gear components are the subject of Chapter 5, while Chapter 6 goes into brake system components.

When you have finished this volume, you will have a mastery of the construction, operation, and maintenance of all representative hydraulic units. You will be well prepared to go on to Volume 3 which takes these units and combines them into operating systems.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TTOC), Chanute AFB, ILL 61868.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB, Alabama 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 27 hours (9 points).

Material in this volume is technically accurate, adequate, and current as of December 1971.

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CHANGES FOR THE TEXT: VOLUME 2

PEN-AND-INK CHANGES:

Page	Paragraph	Line	Correction
13	Fig 19		Correct the last four items on the callouts to read as follows: K. Check valve L. Accumulator M. Check valve N. Selector Valve
27	Fig 31	index K	Change "Annalus" to "Annulus."
27	Fig 32	index K	Change "Annalus" to "Annulus."
41	13-12	3	Change "attitude" to "altitude."
58	16-26	13	Change "B" to "H."

REPLACEMENT PAGES: Insert the following replacement pages: 47 and 48; 63 and 64.

CHAPTER 1

Pneudraulic Terms

YEARS AGO, MAN found that the force of moving water could do great damage. However, he also learned that if he controlled this force, he could make it work for him. For instance, he used waterwheels—dams, flumes, and pipes to pressurize and carry water to fountains. Such devices helped cool and irrigate gardens. These ancient people used the principles of hydraulics; they knew how to use the force of confined water under pressure. The ancient Greeks, who probably were no smarter than some other ancient people, termed these principles hydraulics—their words for water and tube. Although we use oil instead of water, we still call the science hydraulics.

2. Hydraulics is the branch of physics dealing with the mechanical properties of liquids and the application of these properties in engineering. Everytime you open a water faucet, hydraulic force causes water to come out. You may be on a hilltop and the other end of the pipe in a valley miles away. Yet the water forced into the pipe under pressure in the valley will flow from your faucet on the hill. Too, the power steering in your car and the foot brake use the same form of hydraulics as do our most modern aircraft. Did you ever put a hydraulic jack under the axle of your car to change the wheel? The same type hydraulic jack is used to raise the axle of a B–52.

3. This volume is about hydraulic principles and how such principles are applied in order to transmit force in aircraft. It is also about the many different kinds of mechanical units that transmit this force. You will learn about the devices that apply the force to the liquid enclosed in the system. You will also learn about the units that regulate, control, and direct the liquid flow or force. Finally, the components that convert the hydraulic power back into mechanical power at a distant point are covered. In the next section, we will discuss some mechanical properties of liquids, which make hydraulic systems better for transmitting force, in many cases, than electricity or mechanical linkages.

1. Basic Hydraulic Principles

1-1. How do we describe hydraulics as we apply it to aircraft? It is a method of transmitting engine power to distant points in the aircraft. The force is carried by a liquid confined in a system of tubes. To understand this, you must understand certain mechanical characteristics of liquids. You also must know the difference between liquids and fluids. The dictionary defines a fluid as something that is not a solid. It further defines a fluid as any substance that can flow, be it *liquid or gas*. In contrast, a liquid is defined as something that flows, but, unlike a gas, it does not expand indefinitely to *fill the container*. A liquid normally has a definite and level *top surface*. In addition to these facts, you must be aware of three physical laws which deal with liquids.

1-2. **Incompressibility.** For all practical purposes, liquids are considered to be incompressible. Under even *extremely* high pressures a liquid can be compressed only an *extremely* small amount. We normally disregard it. How does incompressibility of a liquid benefit us? An example is the brakes on your car. When you depress the brake pedal the brakes are applied instantly, because no time is lost in compressing the liquid. Think of how long a stroke you would need if the master cylinder contained air.

1-3 **Expansion.** Liquids will expand and contract with their temperatures. When a liquid in a closed container is heated, the liquid expands and exerts pressure on the walls of the vessel. In a hydraulic system it is necessary to place thermal relief valves in various portions of a hydraulic system. All pressurized reservoirs also require thermal relief units. Without these precautions, the expansion of the liquid may become great enough to burst the line, unit, or reservoir.

1-4. **Pressure Transmission.** Pressure is the amount of force applied per unit of area. It is commonly measured in pounds per square inch (psi). Pressure applied to a confined liquid is transmitted equally and undiminished in all directions. This pressure acts at right angles against the walls of the container. This means that the same amount of pressure is exerted on every equal area of a closed system.

2. Flow of Liquids

2-1. Before you can understand how a hydraulic system works, you must have a basic knowledge of the principles governing the flow of liquids. In this volume we will study two major types of liquid flow. This first is flow through tubing. The second is flow through orifices, restrictions, or venturi tubes. Both are important in aircraft hydraulic systems.

2-2. **Liquid Flow in Tubing.** Tubing is used to conduct the flow of pressurized liquid from the power pump to the actuators. When liquid flows in a tube, a shearing action exists between the wall of the tube and the liquid. This results in turbulence along the walls. A turbulent flow is a nonsmooth, whirling flow. Think of the little whirlpools formed at the edges of an oar when it moves through the water. Turbulence creates resistance, and a loss of energy. A rise in temperature of the liquid is evidence of this loss of energy. Wherever there is resistance, there is a loss of energy. When the engineers design an aircraft hydraulic system, they have to consider this loss. They design the tubing and other units to reduce the resistance as much as possible. The power pumps are made large enough to take care of the operational needs *plus* the energy loss.

2-3. When the liquid is motionless in the system, there is no resistance. When it starts to move, the resistance begins; as the velocity increases, the resistance increases. Another factor that effects the amount of resistance is the *viscosity* of the liquid. Viscosity is the characteristic of a liquid that makes it resist flowing. The greater the viscosity, the greater is the resistance.

2-4. Fluid flow , either liquid or gas, is either *laminar* or *turbulent*. Laminar means *in thin layers*. When you think of laminar flow of liquids, imagine the liquid as being in thin layers. The layers are parallel to the directions of flow with the first layer next to the wall of the tube. When the flow speed is low, the friction between layer and layer, and between layer one and the wall is low. In this condition, we say the flow is streamlined, one layer slides smoothly over the next layer or the wall. There is practically no resistance. As the velocity increases however, resistance increases. Where does this resistance develop? First of all, between layer one and the tube wall because the tube wall is stationary. As the velocity increases beyond a certain point, layer one suddenly becomes turbulent. Increase the velocity more, the turbulence will extend into layer two. At this point the other layers are still maintaining laminar flow. Each layer, as you move away from the wall, will flow a little faster than the one before it. Yet, there layers will slide over each other smoothly. Now, if you keep increasing the speed, you will find the *area* of turbulence increasing. Now, for another strange phenomena. You will find that even as you increase the speed in the laminar flow area, the velocity of the turbulent area is dropping. Therefore, now, a small increase in speed of the laminar area causes a faster *spread* of the turbulent area. Suddenly, at a critical velocity, the entire tube cross section becomes turbulent. When this happens, the total flow velocity drops tremendously and suddenly. This, in turn, causes the flow capacity of that diameter tube to drop correspondingly. To prevent this, the engineer must either: reduce causes of friction, reduce the required speed, or enlarge the tube. You will get into the matter of laminar vs. turbulent flow again when we discuss the lift produced by air flowing over a wing surface (the same problem exists there).

2-5. Obviously the design engineers consider many factors when they design aircraft hydraulic systems. First, they must determine the work to be done. Next, the necessary power to do the work. Then, the type of material and units needed to do the work. Finally, they select the chemical makeup, viscosity, and density of the hydraulic fluid to be used.

2-6. **Liquid Flow Through Orifice, Restrictions, or Venturi Tubes.** An orifice is a small hole. We have explained how energy is used to overcome the resistance caused by turbulence. This turbulence was in the liquid flowing through a tube at high speed. If we place an orifice plate or an abrupt restriction in the tube, we get turbulence at low speeds. Therefore, orifices and restrictions in liquid flow are more common causes of energy loss than tubes.

2-7. A venturi is a tube whose cross section area is gradually reduced to a smaller diameter. This narrow point is called the throat. Beyond the throat the tube again gradually enlarges to its original size (see fig. 1). As you see in the figure, there are no abrupt changes in cross section. Therefore, at operational velocities, a laminar liquid flow is maintained. The rate of flow must be the same at the gages before and after the venturi. The gages in the figure show that the pressure is the same. Since the amount of liquid going through the throat is the same as through the larger tube, it *has* to be going faster. The center gage shows that the pressure on the wall of the throat is less than in the tube.

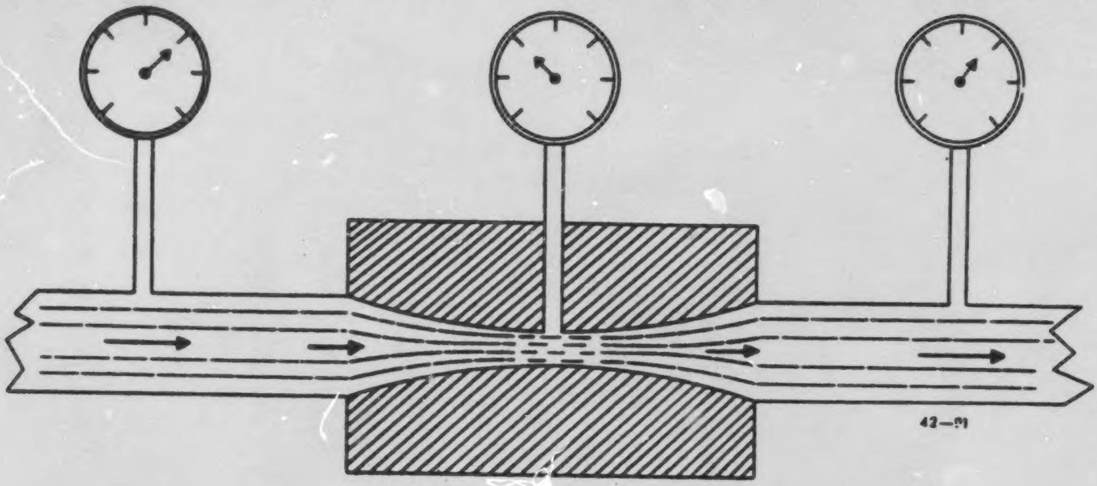


Figure 1. Fluid flow through a venturi.

This is proof of the law of physics that states: *As the velocity of a gas or liquid increases, there will be a corresponding decrease in pressure* (against the walls of the tube).

2-8. This increase in velocity through a venturi can be compared to men marching in a parade. Let's say you are a flight leader commanding the first flight of men in the parade. You are marching your men down a street 16 abreast. Suddenly, you come to a bridge only wide enough for eight men to march abreast. You have to do something to keep the next flight behind you from either halting or slowing to a half-step. What will it be? You quickly form into two flights and double-time the men across the bridge. Immediately after passing over the bridge you reform to 16 abreast and resume normal step. If you didn't resume the normal pace, you would run away from the rest of the formation.

2-9. Fluid flow through a venturi acts in the same way. As the fluid enters the venturi throat it speeds up and reaches maximum speed at the smallest cross section. As it passes out through the enlarging cross sections, it slows down to its original velocity.

2-10. You may wonder where and why a restriction or a venturi is used in a hydraulic system. An orifice or restriction is generally installed in a hydraulic line to limit the rate of flow. As an example, a landing gear, when being extended, will tend to drop with great force. If we install a restrictor in the hydraulic return line, the up line in this case, the velocity of the fluid will decrease. This reduces the speed of extension of the landing gear and prevents possible structural damage.

2-11. A venturi can be used to pressurize hydraulic reservoirs and storage tanks. Pressurization of hydraulic reservoirs will be covered in a later chapter. Right now we will discuss the meaning of some terms we use in hydraulic work.

3. Hydraulic Terms and Laws

3-1. You need to understand hydraulic principles and how they apply to aircraft hydraulic systems. For this, you need to know the *exact* meaning and relationship of several hydraulic terms.

3-2. **Hydraulic Terms.** These terms are explained to you in the following paragraphs. Learn them as thoroughly as you can, because they are vital to your success as an aircraft pneudraulic repairman.

3-3. *Area.* Area is the measurement of a surface. In this course we will express this measurement in square inches. In the aircraft hydraulic system, for instance, we are concerned with the areas of piston heads. Knowing this area, we can figure the amount of force needed to actuate a mechanism.

3-4. *Force.* Force is the amount of push or pull exerted on an object. In this course we measure force in pounds. The force applied to a piston head is the total energy applied to the total area of the piston head.

3-5. *Pressure.* Pressure is the force applied to one unit of area, usually one square inch. In our work we measure pressure in pounds per square inch, or psi. The pressure acting on a piston head develops the force that moves or operates a mechanism.

3-6. *Stroke.* Stroke length is a measurement of distance expressed in inches. It represents the distance a piston moves in a cylinder.

3-7. *Volume.* Volume (displacement)

measurement of quantity, expressed in cubic inches. It represents the amount of liquid contained in a reservoir or displaced by a pump or actuating cylinder.

3-8. *Fluid.* A fluid is any substance that can flow (not solid), liquid or gas. It is able to move and change shape without separating when under pressure. The term "hydraulic fluid" is used in this text as the common name for the oil used in aircraft hydraulic systems.

3-9. In general, fluids *expand* when heated and *contract* when they are cooled. When a confined fluid is heated, pressure on the walls of the confining vessel will increase. Cooling of a confined fluid will cause a decrease in pressure.

3-10. We will learn some important mathematical relationships between the above terms. But, before we do that, let's talk about Pascal's Law.

3-11. **Pascal's Law.** Both mathematical calculations and their practical application in working hydraulic systems are based upon this law. Blaise Pascal (1623–1662) was a noted French mathematician and philosopher whose law is stated as follows: *When a force is exerted on a confined fluid, the pressure is transmitted equally and undiminished in all directions.* Pay particular attention to the words "force" and "pressure." From now on, they, and other terms, must be used according to their strict meaning. Remember that Pascal's law applies only to *confined fluids.* Also, whenever a fluid is in motion in a hydraulic system; this law *does not* apply. This is because when the fluid is flowing it is *not confined* in the true sense of the word.

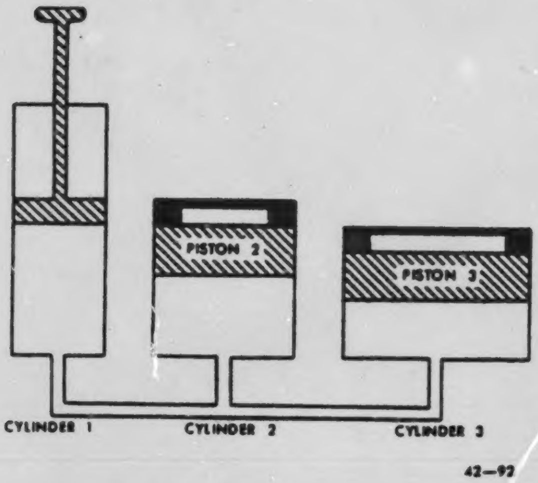


Figure 2. Application of Pascal's law.

3-12. In figure 2 you see Pascal's law illustrated. When a force is applied to the piston in cylinder 1 it is transmitted to all portions of the confined fluid. If the applied force is equal to, let's say, five pounds per square inch, this pressure will press against every square inch of surface in cylinders 1, 2, and 3 and the tubing. It is applied at right angles to the surfaces. That is what Pascal's law says.

3-13. Now a change takes place. A lack of resistance causes either piston 2 or 3, or both, to move upward. This momentarily lowers the pressure in cylinders 2 and 3 while in cylinder 1 it is still 5 pounds per square inch. Obviously, this unbalanced condition cannot last. Fluid will flow from cylinder 1 to cylinders 2 and 3. This is because pistons 2 and 3 are not confining the fluid as long as the move is upward. Hence, Pascal's law does not apply. When pistons 2 and 3 reach the end of their strokes, the fluid flow will have to stop. At this point the fluid is again confined and the pressure again equalizes. Now Pascal's law applies once more.

3-14. We have talked of Blaise Pascal's laws and used hydraulic terms in a general way. Now let's get down to specifics and see how they relate to each other.

4. Relationship of Terms

4-1. We mentioned this before. To understand hydraulics, you must have an understanding of certain specific terms and Pascal's law, and their interrelationship This understanding must become a part of you. The terms "area," "pressure," "force," "stroke," "volume," and the truths spelled out by Pascal are mathematically related. No hydraulic operation is possible without involving these relationships. Why should you, the practical mechanic, be concerned with this theory? Because it is the very foundation of the hydraulic systems. It tells you why the engineer designed it like he did. It enables you to figure out what characteristics he built into the system. To maintain and troubleshoot the systems, this understanding must become instinctive with you. Several factors you must consider are: (1) Why is the system capacity and pressure as selected? (2) What and why are the material strength requirements? (3) What and why are the piston area and stroke requirements? Just what are the various components supposed to do? Etc.

4-2. **Relationship of Force, Pressure, and Area.** If we know any two of these factors, we can easily figure the third. To help in doing this, apply figure 3. Such a triangle is used in several areas of knowledge. To apply it, always multiply the two lower values to get the top value. Or divide the top value by the known lower value to get the other (unknown) lower value. For example, we know that force is the total of the pressures acting in each unit of area. Also, pressure is the total pounds of force divided up between the total square inches of area. To apply the triangle, if you know the values of A and P and want to get F, cover F and multiply A times P. This gives you the value of F. If you know the values of A and F and want P, cover P and divide F by A. If you have the values of P and F and need A, cover A and divide F by P. Remember, F is always given in pounds, P in pounds per square inch, and A in square inches. Now, let's try some problems.

4-3. Example 1: A pressure of 50 pounds per square inch acts on a piston whose surface area is 5 square inches. What is the force acting on the piston? Use figure 3. Cover F and multiply P (50 psi) times A (5 square inches). The result is that F is a force of 250 pounds on the surface of the piston.

4-4. Example 2: A force of 480 pounds is exerted on a surface whose area is 12 square inches. What is the pressure on the surface? Use figure 3 again. Cover P; divide 480 pounds (F) by 12 square inches (A). P will be a pressure of 40 pounds per square inch.

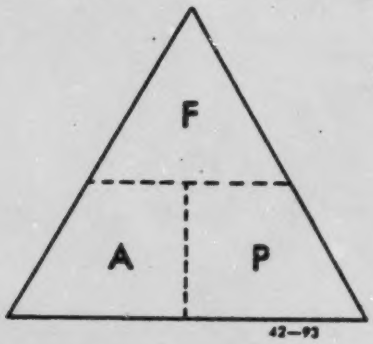


Figure 3. Relationship of force, area, and pressure.

4-5. **Relationship of Volume, Area, and Length.** Figure 4 shows the mathematical relationship between volume, area, and length of stroke. Once again a triangle is used to solve problems involving these three factors. For example, a piston of 8 square inches moves a distance of 10 inches within a cylinder. What is the volume of liquid, displaced by the movement of the piston? Using the triangle in figure 4, we can easily calculate the volume. We cover V and multiply the two lower figures A and L. Eight square inches times 10 inches equals 80 cubic inches (V) which is the volume displaced (V).

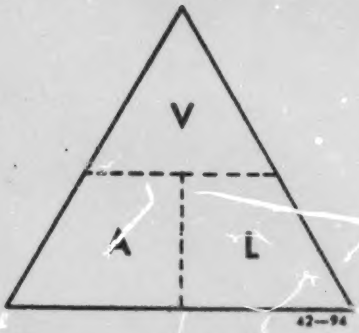


Figure 4. Relationship of volume, area, and length.

4-6. **Practice Exercises—Hydraulic Principles.** The following exercises should give you a better understanding of the relationship of hydraulic factors. Figures are included that are to be used in solving the exercises. The figure legend indicates the practice exercise to which the figure pertains. Answers to these exercises will be found at the end of the chapter.

4-7. **Force-pressure-area exercises.** The first nine exercises will give you actual practice in determining either force, pressure, or area, when two of the factors are known. Refer to figure 5 when solving these exercises. Keep in mind that the cylinder is, of course, full of liquid.

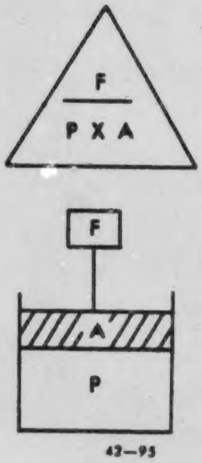


Figure 5. For practice exercises 1 through 9.

1. Find P:

Area = 4 sq in
Force = 100 lbs
Pressure = ____psi

2. Find F:

Area = 10 sq in
Force = ____lbs
Pressure = 100 psi

3. Find A:

Area = ______ sq in
Force = 200 lbs
Pressure = 400 psi

4. Find P:

Area = 6 sq in
Force = 150 lbs
Pressure = ______ psi

5. Find F:

Area = 4 sq in
Force = ______ lbs
Pressure = 300 psi

6. Find A:

Area = ______ sq in
Force = 500 lbs
Pressure = 50 psi

7. Find P:

Area = 3 sq in
Force = 150 lbs
Pressure = ______ psi

8. Find F:

Area = 2 sq in
Force = ______ lbs
Pressure = 1000 psi

9. Find A:

Area = ______ sq in
Force = 750 lbs
Pressure = 1000 psi

4-8. *Volume-length-area exercises.* Exercises 10 through 18 will give you actual practice in determining either volume, length, or area when two of the factors are known. Refer to figure 6 when solving these exercises:

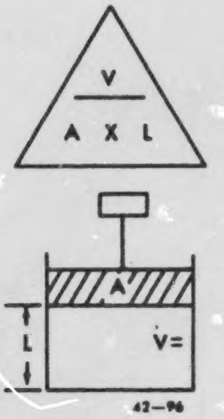


Figure 6. For practice exercises 10 through 18.

10. Find L:

Volume = 10 cu in
Area = 5 sq in
Length = ______ in

11. Find A:

Volume = 20 cu in
Area = ______ sq in
Length = 10 in

12. Find V:

Volume = ______ cu in
Area = 10 sq in
Length = 2 in

13. Find L:

Volume = 15 cu in
Area = 5 sq in
Length = ______ in

14. Find A:

Volume = 10 cu in
Area = ______ sq in
Length = 10 in

15. Find V:

Volume = ______ cu in
Area = 5 sq in
Length = 1 in

16. Find L:

Volume = 10 cu in
Area = 2 sq in
Length = ______ in

17. Find A:

Volume = 5 cu in
Area = ______ sq in
Length = 1 in

18. Find V:

Volume = ______ cu in
Area = 4 sq in
Length = 5 in

4-9. *Force-pressure-area-length-volume exercises.* Exercises 19 through 30 are divided into groups of three. Each group has its own figure shown. Consider each figure as an independent hydraulic system, with the cylinders and connecting tubing full of confined fluid. Each part of the exercises is labeled A and B or A, B, and C to correspond with the cylinders of each figure. With two known factors, the third one can be found by using the triangle formulas. In these exercises, Pascal's law must also be applied to solve them. You will find that at least one part of each exercise has two known factors. By applying the laws of hydraulics for pressure and displacement, you will be able to work the other parts. In the volume exercises, assume that the volumes are transferrable. The fluid in any one cylinder can be moved entirely into the other one or two cylinders.

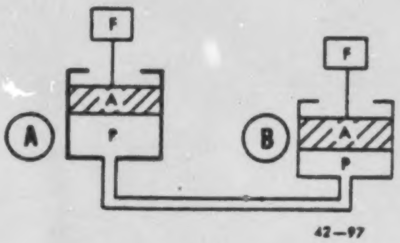
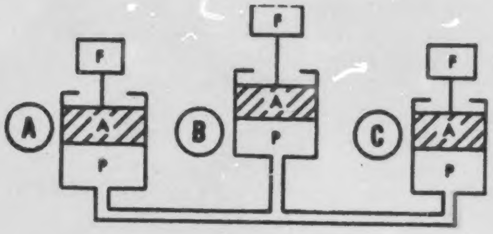


Figure 7. For practice exercises 19 through 21.

	A	B
19.		
	F = 500 lbs	F = ______ lbs
	A = 10 sq in	A = 5 sq in
	P = ____ psi	P = psi
20.		
	F = 800 lbs	F = 1600 lbs
	A = ____ sq in	A = ____ sq in
	P = 400 psi	P = ____ psi

21. A
F = _____ lbs
A = 1 sq in
P = _____ psi

B
F = _____ lbs
A = 2 sq in
P = 200 psi



42—98

Figure 8. For practice exercises 22 through 24.

22. A
F = _____ lbs
P = _____ psi
A = 4 sq in

B
F = _____ lbs
P = 500 psi
A = 2 sq in

C
F = 3000 lbs
P = _____ psi
A = _____ sq in

23. A
F = _____ lbs
P = _____ psi
A = 3 sq in

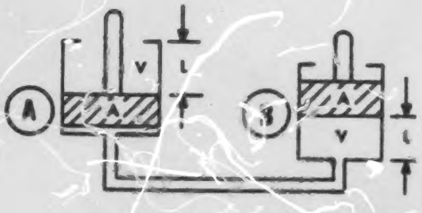
B
F = _____ lbs
P = 500 psi
A = 1 sq in

C
F = 1000 lbs
P = _____ psi
A = _____ sq in

24. A
F = _____ lbs
P = _____ psi
A = 5 sq in

B
F = _____ lbs
P = 100 psi
A = 3 sq in

C
F = 600 lbs
P = _____ psi
A = _____ sq in



42—99

Figure 9. For practice exercises 25 through 27.

25. A
V = _____ cu
A = 10 sq in
L = _____ in

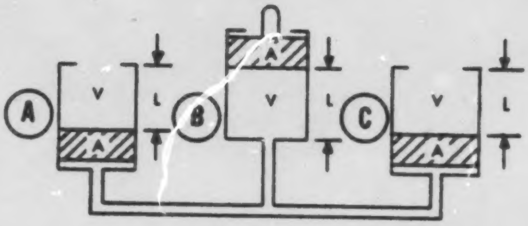
B
V = 40 cu in
A = _____ sq
L = 8 in

26. A
V = 20 cu in
A = _____ sq
L = 4 in

B
V = _____ cu
A = 10 sq in
L = _____ in

27. A
V = _____ cu
A = 5 sq in
L = 3 in

B
V = _____ cu
A = _____ sq
L = 5 in



42—100

Figure 10. For practice exercises 28 through 30.

28. A
V = _____ cu in
A = 2 sq in
L = 5 in

B
V = cu in
A = 4 sq in
L = 10 in

C
V = _____ cu in
A = 6 sq in
L = _____ in

29. A
V = _____ cu in
A = 6 sq in
L = 5 in

B
V = _____ cu in
A = 10 sq in
L = 5 in

C
V = _____ cu in
A = 4 sq in
L = _____ in

30. A
V = _____ cu in
A = 5 sq in
L = 4 in

B
V = _____ cu in
A = 5 sq in
L = 5 in

C
V = _____ cu in
A = [illegible] sq in
L = _____ in

4-10. Of what value to us will this understanding of the interrelationship between force, pressure, area, and length be? Well, in one sense, we are working toward "mechanical advantage" (which we will discuss next.)

5. Mechanical Advantage (MA)

5-1. Can you pull a spike out of a two-by-four with your fingers? Can you lift a car by grabbing a hold on the bumper and grunting? Can the aircraft pilot retract the landing gear by pulling on a rope that is tied to the gear? Of course not. Yet, you can get these jobs done. But, how? By using a claw hammer on the spike, or a jack on the car. On the heavy landing gear, merely moving a handle on a hydraulic selector valve will raise it easily. What thing in common does each of these solutions have? Each example simply makes use of a mechanical device. A man cannot possibly do any of these jobs with his bare hands. The various mechanical devices—hammer, jack, and the hydraulic system—must all do one thing. They must effectively multiply the effort a man can exert to perform work. All of the devices mentioned, and many more, have the ability to multiply the effort applied to the device. As a result, a person can perform acts which he could not otherwise do. The amount by which the *input* effort is multiplied in the output of the device is called the *mechanical advantage*.

5-2. **Importance of MA.** Of what importance is mechanical advantage in relation to the aircraft hydraulic system? At the beginning of this chapter we gave one purpose of the aircraft hydraulic system. It was to transmit engine power to distant points in the aircraft where power is needed. Now we have come to another purpose. That purpose is to multiply the input effort or force enough to do the required job. In other words, to gain a mechanical advantage. We also mentioned the importance of the mathematics of hydraulics to the design engineer. In his mathematical calculations one of his primary interests is mechanical advantage. It enables him to determine accurately the size of actuating cylinders and pistons. Also, it tells him the distance the pistons must move to operate a mechanism. Why is unit size important? Because space in an aircraft is limited. Operating units must be designed to be as strong as necessary, yet small and light as possible.

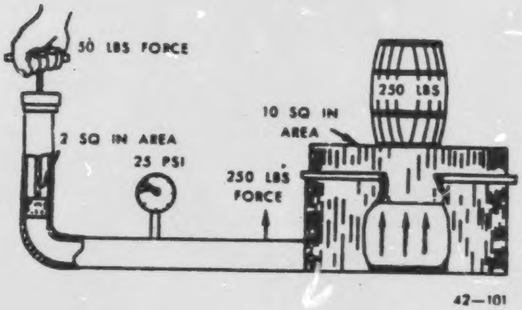


Figure 11. Mechanical advantage.

5-3. In figure 11, you see a simple illustration of mechanical advantage. Note carefully the comparative areas of the small and large pistons. This ratio of sizes is very important. When the 50-pound force is applied to the small piston, the fluid pressure shows 25 psi on the gage. Also notice that 25 psi acting on the large piston exerts an upward force of 250 pounds on it. This will support a 250 pound barrel stationary or raise a 249 pound barrel. This gain in force (from 50 pounds to 250 pounds) is made by increasing the surface area of the output piston. Note two things. The output force is five times as great as the input force. Also, the output piston area is five times as large as the input piston area. Would this 5 to 1 ratio change if the psi were limited to 20? Or raised to 30 psi? No. It will change the forces involved, but the ratio between the forces will still be 5 to 1. Why? Does changing the psi involved change the area ratio?

5-4. **Expression of MA.** Mechanical advantage is expressed as a ratio—in the above case it is 5:1. In hydraulics, mechanical advantage can be explained as the ratio between two pistons with regard to the factors we discussed so far: area and force. The mcehanical advantage ratio serves as a useful shortcut for problems in hydraulics.

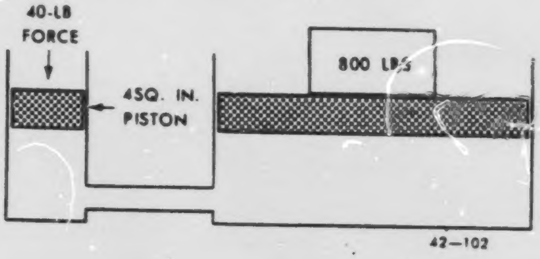


Figure 12. Applying mechanical advantage to problem solving.

5-5. To illustrate, consider the two pistons shown in figure 12 and observe how the MA ratio serves this purpose. In the arrangement shown, assume that we must raise the 800-pound weight by applying a 40-pound force to the 4-square-inch piston. Since MA is the ratio between two values for each of these factors, force and area, we can rapidly calculate the MA. The mechanical advantage in this case can be obtained by dividing 800 pounds by 40 pounds; 20 is the result. Hence, the MA is expressed as the ratio 20:1. Multiplying 20 times 4 square inches (small piston area), we find we need an area on the large piston of 80 square inches. Up to now, we have applied MA only to force and area. It also applies to the distance the pistons move—length of stroke. Apply the MA ratio to the length of stroke and assume that the large piston must move 10 inches. Then we find that the small piston must move 20 times 10, or 200 inches. Of course, it would not be feasible for the small piston to move that far on a single stroke. Therefore, the small piston must move through a series of short repeated strokes. For example, take the case of a hydraulic jack or aircraft hydraulic system hand pump. Notice in this problem that knowing the value of the pressure is not necessary, thanks to the MA ratio. We can find the pressure, however, by merely applying the force-pressure-area triangle, in which case we obtain 10 psi. More of this business of MA involving the distance the piston travels is in the next paragraph. We will also take these principles and apply them to the operation of hydraulic jacks.

6. Mechanical Advantage (MA) and Hydraulic Jacks

6-1. Take a close look at a hand pump that is used to inflate an automobile tire. You should find that it consists of a metal cylinder and a close-fitting piston. When the pump handle is pushed down, the piston forces air from the cylinder into the tire. With each stroke, more air is forced into the tire, and the car slowly begins to rise. But with each stroke, the small amount of air from the pump spreads out into the large tire. The distance the car rises is much less than the distance your hand has to move to push the pump handle down. So there is a gain of force and a loss in distance. Therefore, we can consider the arrangement of the pump and tire to be a machine as it is used to raise the automobile. With some changes, this arrangement of hand pump and tire becomes the "hydraulic jack." This jack consists of a small piston and cylinder connected by means of a tube to a large piston and cylinder. See figure 13. Force is applied to the small piston. This forces fluid through the tube toward the larger piston and causes the larger piston to move.

6-2. **Determining MA of Hydraulic Jack.** How can the MA of the hydraulic jack shown in figure 13 be found? For illustration, we have chosen a square tube that measures exactly 1 inch on each side. This is connected to a larger square tube measuring 3 inches on each side. Assume that the smaller tube is 9 inches high. Therefore, when the piston in the small tube is pushed to the bottom, the amount of fluid forced out is $9 \times 1 \times 1$, or 9 cubic inches. At each complete push, this is the amount of fluid which passes into the larger tube. But, since the larger tube measures 3 inches on each side, the 9 cubic inches here will only rise to a height of 1 inch. Then the 9 cubic inches of fluid in the wide tube occupies a space of $3 \times 3 \times 1$ inch. Thus, the piston in the large tube rises 1 inch when the piston in the small tube moves down 9. In other words, the effort distance (DE) is 9 inches, while the resistance distance (DR) is 1 inch. You can find the MA by using the formula

$$MA = \frac{DE}{DR} = \frac{9}{1} = 9.$$

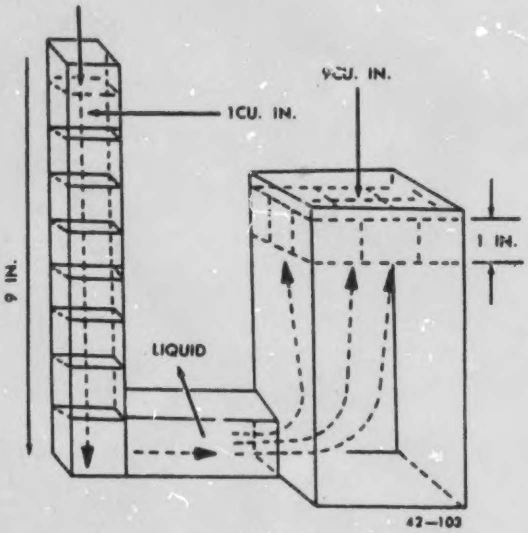


Figure 13. Hydraulic jack principles.

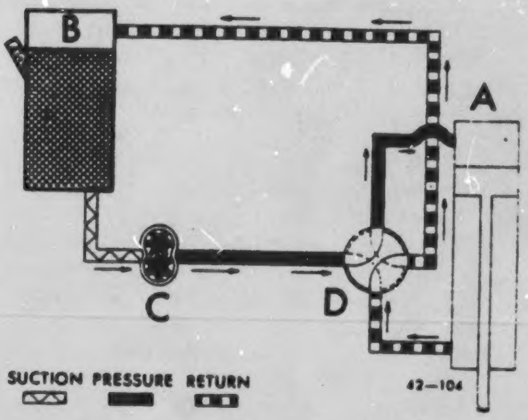
6-3. If the MA is 9, you can lift 90 pounds by applying only 10 pounds of effort to the small piston (discounting friction). You can also find the MA by comparing the areas of the two pistons. The area of the small piston is 1 square inch (1 in x 1 in), while that of the large piston is 9 square inches (3 in x 3 in). The area of the larger piston is 9 times that of the smaller one. This number 9 is also the MA of the jack.

6-4. **Determining Displacement and Head Area.** We used square, rather than round tubes in figure 13 to simplify the mathematics. Although you saw how Pascal's law is used in everyday work to satisfy our needs, the hydraulic jack (schematic shown in figure 13) needs suitable valves before it can operate. The small and large square tubes represent the much more practical round cylinders and pistons. One thing the square tubes have in common with the round cylinders is that both areas are measured in square inches; the displacement or volume is measured in cubic inches. Should you wish to figure the cubic inch displacement (volume) of a cylinder, you can use the formula $V = pi \times R^2 \times H$. Instead of writing pi, you can use the symbol π. For example, the volume of a cylinder 10 inches high (length) with a 2-inch radius is: $V = 3.14 \times 2^2 \times 10 = 3.4 \times 4 \times 10 = 125.6$ cubic inches. To find the area of the piston head, use the formula $A = \pi \times R^2 = 3.14 \times 2^2 = 3.14 \times 4 = 12.56$ square inches.

6-5. This completes our discussion of hydraulic principles. Now examine a basic hydraulic system.

7. Basic Hydraulic System Construction and Operation

7-1. There is a great variety of aircraft hydraulic systems. All of them, the simplest and the complex, operate according to the principles discussed thus far. They are all developments of a basic system. In other words, they are certain units essential to any aircraft hydraulic system. The description of a basic system will help you understand the specific systems to be covered later. We will assign psi and square inch values to operate some of the basic units taught in this section. Their values will be representative of an average. They are not the exact values of any stock numbered item but are used for convenience. Although these are typical values, they need not be remembered as standard values for all hydraulic systems. The development of a basic hydraulic system is shown in figures 14 through 16 and in figure 19. Figure 14 shows only those units that are absolutely necessary to operation.



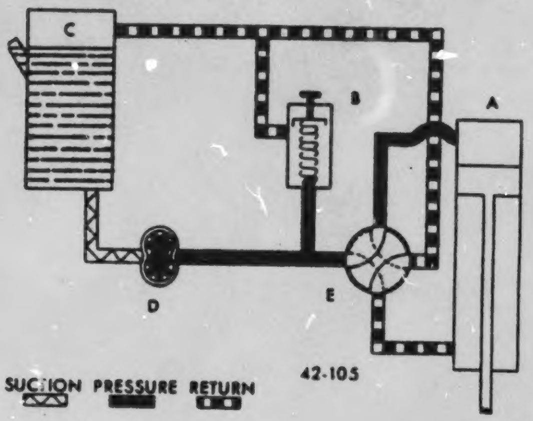
A. Actuating cylinder
B. Reservoir
C. Power pump
D. Selector valve

Figure 14. Simple hydraulic system.

7-2. **Reservoir, Pump, Selector, and Actuator.** Refer to figure 14. The reservoir (B) contains the system fluid. It supplies this fluid to the pump (C) by means of gravity and the suction effect of the pump. Many pumps are driven from an accessory drive of the aircraft engine. Others by an electric motor, or even by air turbines used on some aircraft. In a simple system, as shown in figure 14, a hand-operated pump could also be used. The pump supplies fluid, under pressure, to the selector (directional control) valve (D). This is manually set in either of two positions to control the flow of fluid to the actuating cylinder (A). With the selector valve as in figure 14, fluid is sent to the face of the piston, causing it to move downward. Rotate the selector valve 90°. Now fluid is directed to the back side of the piston, moving it upward. Notice the four ports of the selector valve. The pressure and return ports are directly opposite each other, or 180° apart. The two alternating lines to the actuating cylinder are also opposite each other. The lines are called alternating lines because the direction of the fluid flow alternates in them according to the position of the selector valve. First, an alternating line may provide pressure to the actuator. Then, when the selector valve is turned 90°, the line will become a return line. Alternating lines are also referred to as "up" and "down" lines. The terms refer to the corresponding movements of the mechanism (landing gear, wing flaps, dive flaps, etc.). The terms "up" and "down" have no connections with the movement of the actuating cylinder piston itself. The piston might move in one direction while the mechanism moves in the opposite direction; it depends upon the mechanical linkage arrangement between the two.

7-3. An example of this would be a landing gear system. Ordinarily, it takes more force to retract a gear than to extend it. We know that the larger the area exposed to a given pressure, the greater the force that will be developed. Therefore, pressure applied to the face of the piston opposite the rod side will yield more force. The piston back side area is equal to the face side area, *minus* the rod cross sectional area.

7-4. Notice the solid and dotted lines in the selector valve in figure 14. They show the two possible positions of the flow director. In this figure, fluid under pressure is directed through the up line into one end of the actuating cylinder. The piston is forced to move to the opposite end of the cylinder. As it moves, two events take place. The mechanism (landing gear, flaps, etc.), attached by mechanical linkage to the actuating cylinder piston rod, moves up. When this happens the piston pushes static fluid out of the cylinder. This flows through the down line and selector valve into the return line, and then to the reservoir. When the selector valve is turned to the position shown by the dotted lines, the down line becomes the pressure line. This pressure on the back side of the piston moves it back through the length of the cylinder. When this happens, the mechanism moves down (extends). The up line returns static fluid to the reservoir through the selector valve and return line. Some selector valves have a neutral position in which they can block off both alternate lines. In this case, the trapped fluid in both ends of the piston will hold the piston in a locked position.



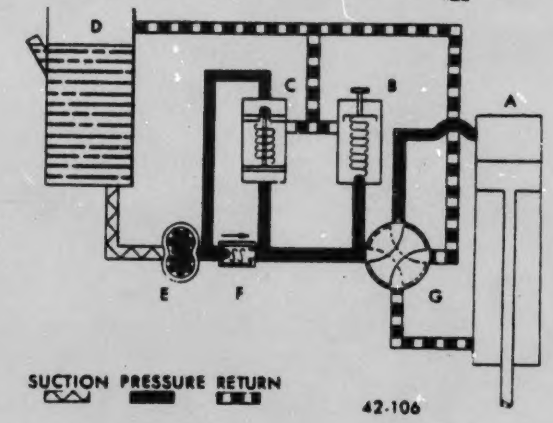
A. Actuating cylinder
B. Relief valve
C. Reservoir
D. Power pump
E. Selector valve

Figure 15. Simple system with relief valve.

7-5. **Relief Valve.** The hydraulic system just described would be practical if it were operated by a hand pump. However, if any kind of power pump is used, pressure will build up immediately. It will build up to such proportions that something will have to give. Either the pump will fail under such a load or a line will burst. Therefore, we must add units that will allow the system to operate from a power-driven pump. To properly design a system, we must know the pressure needed to operate the mechanism. Then we must add some device to relieve any pressure that is above the required pressure. Such a device is the system relief valve (item B in figure 15). It is so constructed that a ball or poppet is held on its seat by a spring. System fluid pressure will unseat the ball and flow by it into the return line when it overcomes the spring pressure. This happens whenever the actuating cylinder is not moving and the pressure is at a maximum. Fluid is then bypassed through the relief valve and returned to the reservoir. The valve remains open as long as the pump operates, or until the selector valve is repositioned. Spring pressure is adjustable to match the design pressure for any specific system. When the piston reaches either end of the cylinder, it stops, then the fluid flow that drove it stops also. Immediately the pump builds up the system pressure tremendously. Before this pressure can rupture the tubing or damage the system units, it will overcome the relief valve spring setting. With this, the ball will push off its seat, and excess fluid will be bypassed to the reservoir.

7-6. At this point we have a workable system, but it is still impractical. After a few hours of constant load operation, an ordinary pump would probably fail. This would be true here. Practically all the time the pump would be bucking the relief valve with system pressure at maximum. Now add to the system some units that will relieve the workload of the pump. They will make the system more efficient, safe, and durable. The addition of a pressure regulator and a check valve to the system (see fig. 16) does this.

7-7. **Pressure Regulator and Check Valve.** You should first know something about the general construction and purpose of a check valve. The purpose of this valve is to permit the flow of fluid in one direction; it prevents flow in the opposite direction. The type of check valve shown as item F in figure 16 contains a steel ball that is spring-loaded on its seat. It takes about 3 to 5 psi of pressure to compress the spring and move the ball from its seat.



A. Actuating cylinder
B. Relief valve
C. Pressure regulator
D. Reservoir
E. Power pump
F. Check valve
G. Selector valve

Figure 16. Simple system with pressure regulator and check valve.

7-8. The check valve allows the pump to pump fluid into the system with little hindrance. But, if the pressure on the pump side drops to near or below the pressure on the system side, the ball seats itself. The downstream system pressure and spring pressure together seat the ball, and the system pressure is trapped until used. You are probably asking this question: If the pump is running, how can the pressure on the pump side ever get below the pressure on the system side?

7-9. The pressure regulator or unloading valve (C) maintains system pressure between two designed pressure limits. It relieves the pump side and, therefore, relieves the pump when no mechanisms are being actuated. A typical pressure regulator in its two phases of operation is shown in figures 17 and 18. We now can apply the mathematical relationship between pressure, area, and force to teach its operation. The regulator has two positions, "kicked in" (fig. 17) and "kicked out" (fig. 18). Notice that as the fluid is delivered from the pump, it goes to both the top and the bottom of the regulator. The construction of the regulator includes a piston 1 square inch in area, a piston rod, a steel ball 1/4 square inch in area, and a piston spring of 600 pounds force pushing the piston down. Until the pressure is great enough to push the piston up and unseat the ball, the fluid is directed to the system.

7-10. Let us suppose that the pressure has built up to 600 psi. Remembering our formulas, we know that pressure times area equals force. Thus, 600 psi times 1 square inch (area of piston) equals 600 pounds of force acting upward. Since the spring pushes the piston down with a force of 600 pounds, we can say that these two forces are balanced. But don't forget that we also have the 600 psi acting downward on the 1/4-square-inch area of the steel ball. Applying the formula, we find that this steel ball area provides another 150 pounds of force. This 150 pounds plus the 600 pounds of spring tension continues to hold the ball on its seat. Fluid pressure, therefore, increases in the system momentarily. In figure 17, the pressure has built up to 800 psi, or 800 pounds of force, pushing up on the piston. The spring pushes down with 600 pounds, so the excess in force is 200 pounds pushing the piston up. Again, we have the same 800 psi acting on the 1/4-square-inch area of the steel ball. Now the steel ball area is equal to a force of 200 pounds pushing down. At this point we may say that the regulator is in a balanced state. Any pressure in excess of 800 psi will move the piston up and push the ball off its seat. We know that the fluid will always follow the path of least resistance. Therefore, it will pass through the regulator and back to the reservoir (see fig. 18).

7-11. Now we can see the importance of the check valve. This "opening" of the regulator causes a rapid loss of pressure in the top line on the left side of the check valve. With this sudden reduction in pressure, the check valve snaps shut. The fluid trapped to the right of the check valve continues to hold the regulator piston raised. Now the total output of the pump moves unrestrictedly through the regulator, to the return line, and back to the reservoir. Since the load on the pump is removed, the pump is said to "idle." As soon as the regulator ball is off its seat, there is no pressure acting on it, thus no downward force. Therefore, 800 psi is holding the piston up against the 600-pound force of the spring. The pressure in the system must drop slightly below the 600-pound spring force before the regulator ball can reseat. When that happens the pressure in the system can build up again through the reopening check valve.

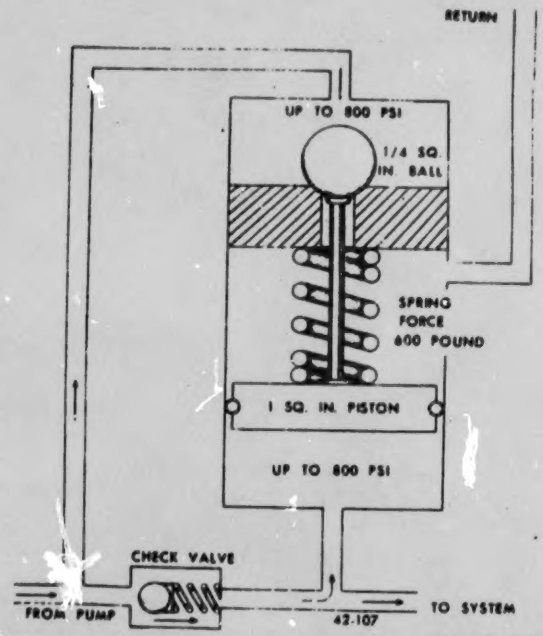


Figure 17. Pressure regulator "kicked in."

7-12. Because we added the pressure regulator to the system, the relief valve now becomes an emergency-type valve. Its purpose is to prevent damage to the system only if the pressure regulator should become inoperative. Should this happen, remember that the pump cannot idle; it must maintain the pressure necessary to hold the relief valve open.

7-13. Let us complete the basic hydraulic system (see fig. 19) by adding an accumulator (I), two more check valves (M and H), and a hand pump (G). The accumulator is a part of the main system. The hand pump is an auxiliary emergency unit, and the check valve (H) works with the hand pump.

7-14. **Accumulator.** The accumulator is a steel sphere divided into two chambers by a synthetic rubber diaphragm. The upper chamber contains fluid at system pressure, while the lower chamber is charged with air.

7-15. The accumulator serves three functions. Primarily, it prevents the pressure regulator from repeatedly "kicking out" (opening) and "kicking in" (closing). Furthermore, it prevents strain on system units by acting as a shock absorber for sudden pressure surges. Finally, it "stores" hydraulic fluid under pressure; it supplements the pump during sudden demands; it supplies fluid for a limited operation of mechanisms should the pump break down.

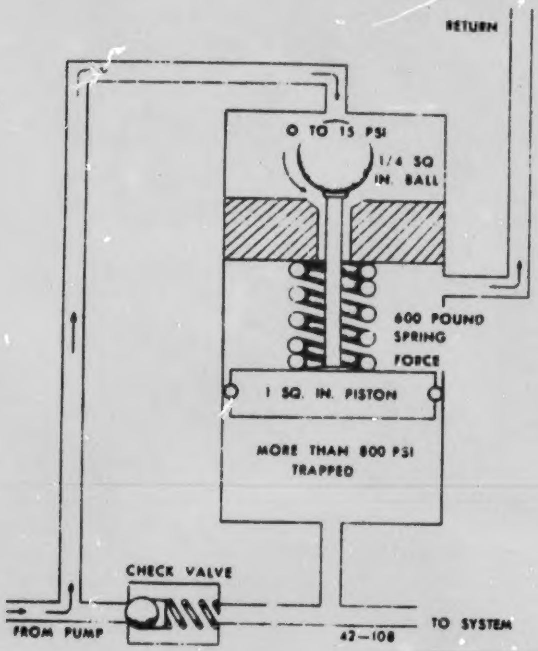
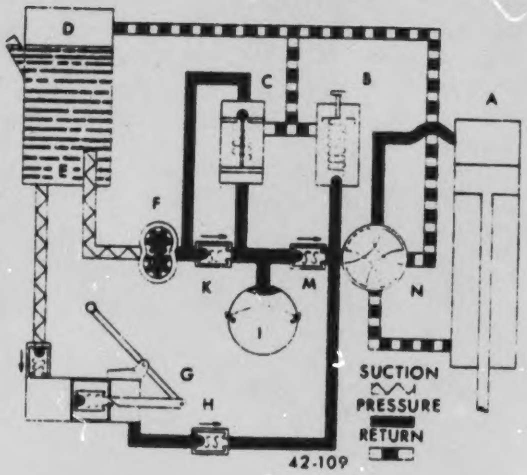


Figure 18. Pressure regulator "kicked out."

7-16. When the pressure regulator operates, its moving parts travel rapidly and with great force. Therefore, to prevent excessive wear, the unit should operate only when necessary. Just how does the accumulator prevent excessive regulator operation? Earlier in this chapter we described fluids as being incompressible. This characteristic of fluid makes the accumulator necessary. In figure 18, the pressure regulator is in the "kicked-out" position, and the pump is idling. Fluid under pressure is trapped in the system to the right of the check valve.

7-17. Remember that the pressure of the trapped fluid is 800 psi. Now, theoretically, if one drop of fluid were to leak out the system, the pressure would immediately drop to zero. This is because fluid cannot be compressed like air; the space that one drop occupies can completely relieve all the pressure. Should this happen, the regulator would "kick in;" the pump would build the pressure to 800 psi, and the regulator would "kick out" again.



A. Actuating cylinder
B. Relief valve
C. Pressure regulator
D. Reservoir
E. Reservoir standpipe
F. Power pump
G. Hand pump
H. Check valve
J. Check valve
K. Accumulator
L. Check valve
M. Selector valve

Figure 19. Complete basic hydraulic system.

7-18. This cycle would continue indefinitely, and eventually the regulator would break down. With an accumulator (see fig. 19) in the system, however, such a condition can be eliminated. The regulator will remain in the "kicked-out" position longer. Slight internal leakage will merely result in a gradual reduction of system pressure. As fluid leaks to the return lines, rapid loss in pressure is prevented by the accumulator air charge. In time, the pressure will drop to the "kick in" setting of the regulator. The pressure does not fall immediately to zero because of the air charge in the accumulator. This air pressure pushes the diaphragm up against the fluid. In other words, the fluid in the system has, in effect, taken on the characteristics of compressed air; it thereby keeps the pressure regulator from overworking.

7-19. How does the accumulator accomplish its shock-absorbing function? Once again the answer lies in the air charge in the accumulator. The following is an example. When a selector valve is moved, there is an immediate drop in system pressure. A port is opened to the fluid return line and pressure on the outflow side of the piston drops. As the piston nears the end of its stroke, the pressure begins to increase; when the piston reaches the end of its stroke, there is a sudden buildup of pressure; immediately, the accumulator air charge is repressurized and the pressure regulator "kicks out." Without the air cushion provided by the air charge in the accumulator, damage could occur to the system.

Pressure build ups would be extremely sudden and sharp because of the incompressibility of the fluid.

7-20. The accumulator is a relatively large container designed to retain a compressed air charge. Because of its rubber diaphragm divider, it will effectively store fluid under pressure. Hydraulic pressures can be lost because of pump failure or a stuck-open pressure regulator. In such a case, the pressurized fluid in the accumulator saves the situation. It normally is enough to actuate at least one mechanism, possibly more.

7-21. **Hand Pump.** The hand pump shown in figure 19 serves two purposes. It can be used as an emergency source of pressure if the power pump fails during flight. It is an auxiliary source of pressure for ground checking the operation of the system units.

7-22. Notice that the hand pump assembly consists of a cylinder, piston, a piston rod, and two check valves. When the piston moves to the right, the check valve in the piston is held closed by the spring. The piston forces the fluid in the right chamber out into the pressure line through check valve. At the same time, the suction effect of the moving piston draws fluid through the inlet line check valve. This fills the left pump chamber.

7-23. When the piston is moved to the left, the inlet line check valve is held closed by the pressure of the fluid in the left chamber. The space available for the fluid in the right chamber is less than the space in the left chamber. This is caused by the piston rod displacement in the right chamber; thus, the excess fluid under pressure is driven out through the discharge port of the system.

7-24. Failure of either of the pump check valves will cause the pump to become completely inoperative. To prevent this, we install a check valve (H) in the discharge line. Now, any one of the three check valves could fail and the pump would still produce pressure on at least one stroke of the cycle. This is the type of pump used in almost all aircraft hydraulic systems; practically all hydraulic systems make provisions for an installed check valve (H) in the pressure line.

7-25. The function of the system check valve (M, fig. 19) is to prevent fluid delivered by the hand pump, from entering the accumulator. Since the hand pump is an emergency or auxiliary device, we want quick action from it. We don't want to waste energy filling the accumulator before directing fluid to the mechanism being operated. The check valve (M) closes when the pressure from the hand pump exceeds the static pressure to the left of the valve. Thus, the hand pump fluid output flows directly to the mechanism being actuated.

7-26. Another particular condition might arise while the power pump is operating. There could be a system leak large enough to cause fluid loss down to the top of the standpipe (E) in the reservoir. (See fig. 19.) In such a case there is still an emergency supply of fluid available for the hand pump. We do not want to lose it by pumping it into the accumulator. Here again we see the importance of the check valve (M).

7-27. **The Complete Hydraulic Installation.** In most aircraft hydraulic installations, several subsystems are operated from the main system. Over the years there has been an increase in the number and size of units to be actuated. This increase, in turn, has increased the power requirement. As a result, more pumps — and more improved lines, fittings, valves, and disconnects — are needed. In most subsystems the actuating units are connected in parallel. They may be like or unlike units. Also, it may be necessary to synchronize their movement. The unit requiring the lowest pressure will operate first. It may move to the end of its travel before the next unit begins to move. In some systems it is desirable to have a certain sequence of unit operation. Also, varying speeds and operating pressures may be desirable; for safety purposes, an emergency system must be incorporated.

7-28. To get the desired results from a hydraulic system often requires specially designed units. To understand our modern aircraft hydraulic systems, you must gain a fund of knowledge. You must be thoroughly familiar with the pertinent principles. You must also know the construction and operation of each unit used in hydraulic systems, or at least of representative types of each unit. In later chapters we shall discuss units typical of those used in the various aircraft systems.

Answer to Practice Exercises

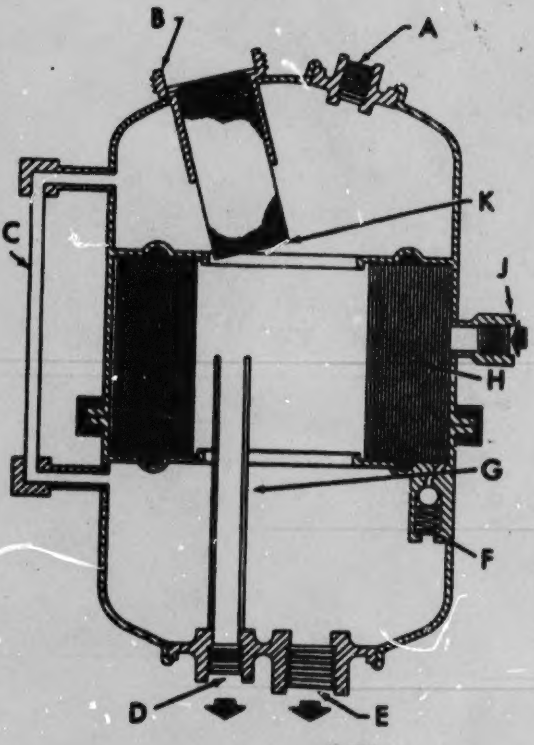
1. 25 psi
2. 1000 lbs
3. 0.5 sq in
4. 25 psi
5. 1200 lbs
6. 10 sq in
7. 50 psi
8. 2000 lbs
9. 0.75 sq in
10. 2 in
11. 2 sq in
12. 20 cu in
13. 3 in
14. 1 sq in
15. 5 cu in
16. 5 in
17. 5 sq in
18. 20 cu in
19. A. P = 50 psi
    B. F = 250 lbs
    B. P = 50 psi
20. A. A = 2 sq in
    B. A = 4 sq in
    B. P = 400 psi
21. A. F = 200 lbs
    A. P = 200 psi
    B. F = 400 lbs
22. A. F = 2000 lbs
    A. P = 500 psi
    B. F = 1000 lbs
    C. P = 500 psi
    C. A = 6 sq in
23. A. F = 1500 lbs
    A. P = 500 psi
    B. F = 500 lbs
    C. P = 500 psi
    C. A = 2 sq in
24. A. F = 500 lbs
    A. P = 100 psi
    B. F = 300 lbs
    C. P = 100 psi
    C. A = 6 sq in
25. A. V = 40 cu in
    A. L = 4 in
    B. A = 5 sq in
26. A. A = 5 sq in
    B. V = 20 cu in
    B. L = 2 in
27. A. V = 15 cu in
    B. V = 15 cu in
    B. A = 3 sq in
28. A. V = 10 cu in
    B. V = 40 cu in
    C. V = 30 cu in
    C. L = 5 in
29. A. V = 30 cu in
    B. V = 50 cu in
    C. V = 20 cu in
    C. L = 5 in
30. A. V = 20 cu in
    B. V = 25 cu in
    C. V = 5 cu in
    C. L = 1 in

Pneudraulic System Supply Units

IN CHAPTER 1, we discussed hydraulic principles, laws, basic units, and basic systems. We hope that this discussion has strengthened your insight into these laws and principles. They *determine* how units and systems will be built. They determine what units and systems can and cannot do. It is important that you have a basic knowledge of the principles of operation of these units. This will help you in order to understand the function of any hydraulic system. You may frequently be called upon to diagnose aircraft hydraulic system troubles; you can do this only if you are familiar with the units in the system. With this knowledge, you will be equipped to more easily isolate system troubles. Remember — *know your system! Know your units!*

2. The level of maintenance that you are to perform determines the extent to which you should be trained. The depot level requires overhaul, repair, and testing of individual units. There the mechanic should be a highly trained technician in his particular field. The intermediate maintenance level performs periodic inspections, troubleshooting, and removal and replacement of units. It requires well-trained mechanics who know the aircraft and especially the system related to their particular skills. Organizational maintenance personnel perform the everyday servicing and upkeep of the aircraft. At this level, work may be performed by mechanics with less intensive knowledge in a specialty. At any time you may be assigned to any one of these maintenance levels; therefore, the more thoroughly you are trained, the more the Air Force and you will benefit by your knowledge.

3. The units that we shall describe in this and the following chapters may be divided into groups. The first group contains those units necessary to provide the system with a fluid supply. It includes reservoirs, filters, hand pumps, power pumps, and accumulators.

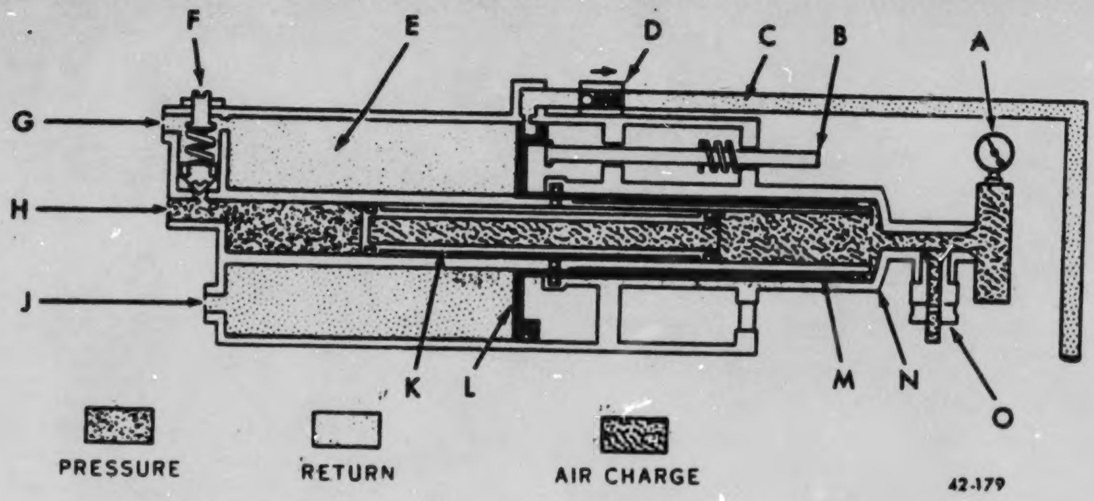


A. Pressurization air port	F. Relief valve
B. Filler neck	G. Standpipe
C. Sight gage	H. Filter element
D. Power pump outlet	J. Return port
E. Hand pump outlet	K. Screen

Figure 20. Typical hydraulic fluid reservoir.

8. Hydraulic Fluid Reservoirs

8-1. The reservoir is the fluid "storehouse" for the aircraft hydraulic system. It contains enough fluid to supply the normal operating needs of the system. It also needs to contain an additional supply to replace fluid lost through minor leakage. Construction of the reservoir varies with different aircraft, but all types serve the same purposes.



A. Pressure gage
B. Indicator pin
C. Overboard vent line
D. Check valve
E. Reservoir
F. Relief valve
G. System return line
H. System pressure line
J. Pump supply line
K. Accumulator piston
L. Reservoir piston
Reservoir piston extension
M. Accumulator
N. Filler valve

Figure 21. Piston-pressurized reservoir (air type).

8-2. All reservoirs have a data plate near the filler cap; refer to it before servicing the system. This data plate gives the specification of the required fluid, its color, and the capacity of the system. It gives the required setting for various mechanisms as well as instructions for filling the reservoir.

8-3. Most of our modern aircraft fly at very high altitudes where the atmospheric pressure is low. To insure that the pumps are being constantly supplied with fluid, the reservoir must be pressurized. This can be done by one of several methods: the venturi tee, the jet pump, or by compressed air from the jet engines.

8-4. **Conventional Reservoirs.** A conventional reservoir is shown in figure 20. Most reservoirs of this type have a space above the fluid, even when they are full. This allows the fluid to foam and thus purge itself of air bubbles that are normally picked up. In unpressurized reservoirs, the pressurization air port (A) serves as an overboard vent. In this case the line contains a check valve to prevent fluid loss during acrobatics. The sight gage (C) gives a visual indication of the amount of fluid in the reservoir. This is an added precaution to prevent foreign matter from entering the system. The reservoir is serviced through the filler neck (B) and screen (K). Under no circumstances should the reservoir be serviced with hydraulic fluid of unknown origin. A new can should be opened when you fill the system. To further insure cleanliness, the fluid entering through the return port (J) passes through a filter element (H) before returning into the system. Should the filter element become clogged, the relief valve (F) will open. It is set to open at pressures more than 12 psi, where upon the fluid will enter the reservior.

8-5. On some aircraft the emergency hydraulic system gets its fluid from the main system reservior. In such systems, a standpipe (G), is connected to the main system or power pump outlet (D). Suppose that a line were to rupture somewhere in the main system. If so, the pump would continue to pump fluid overboard until the supply became exhausted. Also, we would find it impossible to maintain any pressure in the system. Therefore, the emergency system must be used. The standpipe prevents the main system pump from taking fluid whenever the level drops below the top of the standpipe. This keeps enough fluid in the bottom of the reservior to supply the hand pump for emergencies. The fluid is taken out through the hand pump outlet (E).

8-6. On other aircraft a separate emergency reservoir is used for emergency operation. The hand pump, you remember, serves two purposes — emergency operation and ground test. Usually, the emergency reservoir fluid supply is not used for ground test. Therefore, a ground test selector valve is used to select the source of fluid supply for the hand pump. Design of emergency systems in aircraft varies even more than that of normal systems. Every aircraft has its own specific emergency requirements. The selector valve, then, will send fluid from either the main or the emergency tank to the pump. From the main supply tank, the fluid may be taken from either the standpipe or the bottom. The selector valve lets us ground test with main reservoir fluid in the hand pump. During flight emergencies the hand pump uses emergency reservoir fluid. Whenever the hand pump is inoperative on the ground, check the fluid level in the reservoir. It may be low.

8-7. **Piston-Pressurized Reservoirs (Air Type).** Reservoirs used on most aircraft vary somewhat in construction from the one shown in figure 20; however, they still serve the same purpose. Figure 21 shows an example of a more radically designed reservoir.

8-8. Refer to figure 21; notice that the reservoir, accumulator, and relief valve are constructed as a single unit. The reservoir (E) portion of the assembly is a cylinder that surrounds a cylindrical accumulator (N). The reservoir is ported to the pump supply line at (J) and system return line at (G). Therefore, the system return line, the reservoir fluid, and the pump supply line are pressurized to the same value.

8-9. The accumulator (N) portion of the assembly contains a hollow piston (K). The piston separates the system pressure fluid chamber from the preload chamber. It could be said that the accumulator (N) has three purposes: it dampens pressure surges in the system; it keeps the fluid in the reservoir under pressure to prevent pump cavitation, and it stores fluid under pressure. The preload chamber, on this particular assembly, is charged with dry nitrogen to 2000 psi. It is charged through the filler valve (0) and is indicated on the pressure gage (A). The main system relief valve (F), connects the accumulator fluid chamber and the surrounding reservoir fluid chamber. It protects the system from excessive pressures.

8-10. How is the reservoir pressurized? Refer to figure 21 again. The black portion of the drawing represents a cutaway view of the reservoir piston (L). The black portion that extends to the right represents the extension of the reservoir piston. The nitrogen charge in the preload chamber can act on the end of the piston extension (M). The piston extension area on which the nitrogen charge acts is small. Yet it is large enough to force the reservoir piston (L) to the left. This causes the piston head to pressurize the reservoir fluid to 60 psi when the pumps aren't running. When the power pumps are operating the system pressure line (H) is pressurized to 3000 psi. This automatically increases the nitrogen pressure to 3000 psi through movement of the accumulator piston (K). This increased nitrogen pressure will cause the reservoir piston (L) to be forced to the left. It will move with enough force to pressurize the reservoir fluid to 90 psi.

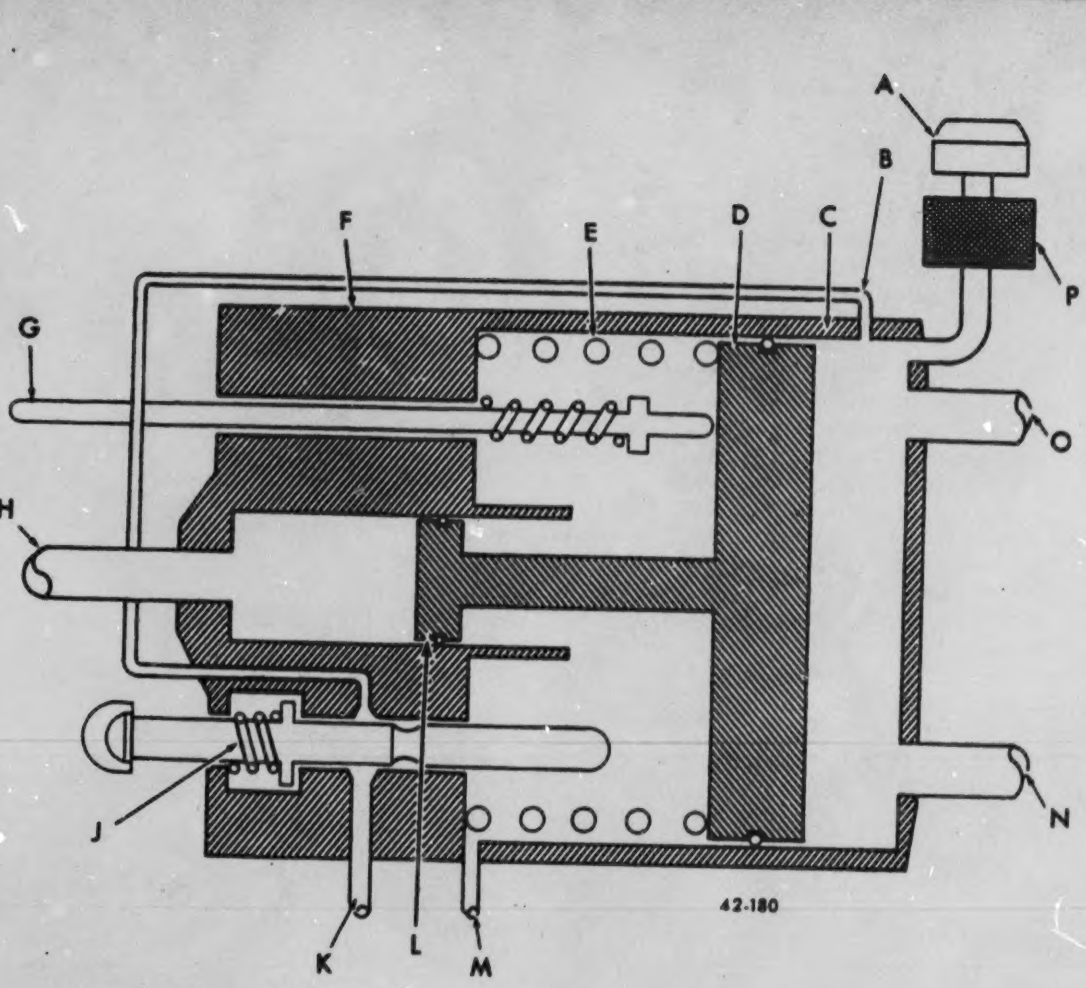
8-11. The indicator pin (B) in figure 21 tells you when the system needs servicing with fluid. When the pin is flush with the reservoir housing, the system needs fluid. Servicing the reservoir is quite easy. A portable test stand is hooked to the return line (G), and fluid is pumped into the system. Adding fluid causes the reservoir piston (L) to move to the right. When the reservoir is full, the movement of the piston pushes the indicator pin (B) out. The reservoir is built so it cannot be overfilled. Notice the position of the reservoir piston (L) in figure 21. If it moves any further to the right it opens a drain port to the overboard vent line (C). All excess fluid will dump overboard through this port as fast as it is pumped in. Because of aircraft configuration (arrangements of parts), all fluid does not always drain out of the overboard vent line. When the system loses fluid, the piston (L) will move to the left. This opens the drain port to the backside of the piston. Now the trapped fluid in the vent line (C) can drain back into the area behind the piston (L). From there it will leak into the fuselage past the indicator pin (B). To prevent this back flow, check valve (D) is put into the overboard vent line (C).

8-12. **Piston-Pressurized Reservoirs (Airless Type).** The air-type reservoir just discussed uses air pressure to pressurize the fluid. Now we will discuss a type that uses spring tension and systems pressure to pressurize the reservoir.

8-13. Refer to figure 22. The reservoir consists of a barrel (C), with pump supply line (N), system return line (O), filler valve (A), and relief valve vent line (B). Therefore, all these lines are pressurized to the same value. They are also the same as the fluid confined to the area between the reservoir piston (D) face and the barrel (C).

8-14. The opposite end of the reservoir is referred to as the head (F). It contains piston spring (E), pressurization piston (L), system pressure line (H), indicator rod (G), and relief valve (J).

8-15. Now, how is the reservoir pressurized? With the reservoir at the full level, the piston spring (E) will force the reservoir piston (D) to the right. This pressurizes the reservoir fluid to 5 psi when the system is in operation. When the power pump is operating, the system pressure



A. Filler valve
B. Relief valve vent line
C. Barrel
D. Reservoir piston
E. Piston spring
F. Head
G. Indicator rod
H. System pressure line
J. Relief valve
K. Overboard vent
L. Pressurization piston
M. Overboard drain
N. Pump supply line
O. System return line
P. Filter

Figure 22. Piston-pressurized reservoir (airless type).

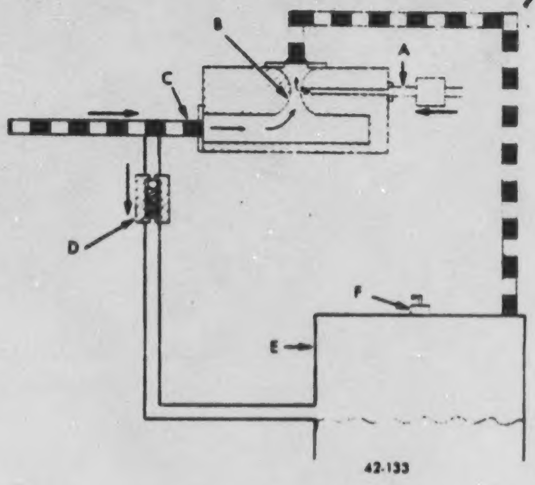
line (H) is pressurized to 3000 psi. System pressure acting on the pressurization piston (L) will cause the reservoir piston (D) to push harder to the right. This increased force will be enough to pressurize the reservoir fluid to 30 psi. Referring to figure 22, notice that any leakage past the piston (D and L) seals should drain off. Overboard drain line (M) in the lower section of the reservoir barrel (C) permits this.

8-16. The reservoir is pressure filled through a self-sealing filler valve (A), using a portable test stand. When not in use, the filler valve is protected by a dust cap. An in-line screen-type filter (P) is installed in the fill line. It prevents foreign objects from entering the reservoir during servicing operation. A direct reading indicator rod (G) is mounted in the reservoir head (F). It is a spring-loaded rod, visible through a slot in the indicator housing. Reservoir content is shown by an index mark on the indicator rod. This index mark moves between the FULL and REFILL marks on the indicator housing.

8-17. A relief valve (J) is mounted in the head (F). It is connected to the barrel (C) through an external relief valve vent line (B). If the reservoir is overserviced, the reservoir piston (D) will push against the relief valve (J and open it. This allows the excess fluid to drain out the overboard vent (K). This valve can also be pulled out manually. This permits the relief valve (I) to be used for draining and bleeding operations.

8-18. **Hydraulic Reservoir Pressurization.** In most hydraulic systems, it is necessary to pressurize the fluid reservoir. This is especially true in high altitude-type aircraft. As altitude increases, atmospheric pressure decreases. With little or no pressure on the fluid, it tends to foam. Foaming in the reservoir causes air bubbles to form throughout the fluid, thus introducing air into the system. Also, the pumps will be starved for fluid at high altitudes unless some means of pressurization is used. At high altitude the atmospheric pressure is very low. There is very little pressure pushing down on the fluid in an unpressurized reservoir. This can result in cavitation (the development of a cavity) in the suction line of the power pump. That is just what happens when the suction of the pump suddenly creates a vacuum cavity in the suction line. The effect is like a vapor lock on an automobile fuel pump. The remedy is to pressurize the supply tank. There are several methods of pressurizing a reservoir. The desired pressure to be maintained ranges from approximately 4 psi to 35 psi. The exact psi depends upon the type of system used. The pressure is held at the proper value by the use of an air pressure regulator. The regulator contains a relief valve for use in case of regulator failure. Some systems receive the air pressure directly from the aircraft cabin pressurization system. Jet aircraft systems receive the pressure from the engine compressor section. In some systems, an additional hydraulic or electric pump is installed in the fluid outlet line of the reservoir. This insures a positive flow and pressure to the power pumps.

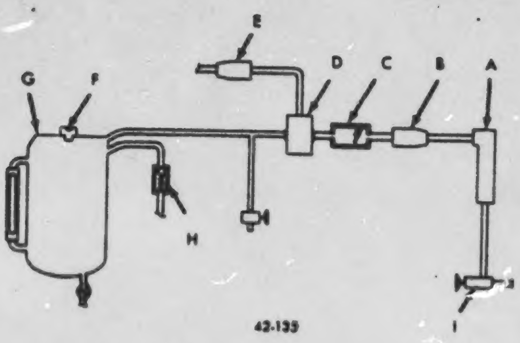
8-19. *Venturi-tee method of reservoir pressurization.* The schematic of the venturi-tee method of reservoir pressurization is shown in figure 23. This method works on the principle of fluid flow through a venturi that we discussed earlier. Turn back to figure 1; notice that it shows a pressure drop where fluid passes through the center of the venturi. In the system shown in figure 23, you can see that the return flow from C passes through a venturi tee (B). From there it enters the reservoir. The low-pressure area at the center of the venturi draws in filtered air through the passageway (A). The combination of fluid and air then continues on into the reservoir (E). Within the reservoir, the air leaves the fluid and rises to the top of the airtight reservoir; there it builds up an internal pressure. A reservoir relief valve (F) prevents air pressure from exceeding the desired pressure. Another relief valve (D) allows any return fluid in excess of 20 psi to bypass the venturi tee.



A. Air passage to venturi
B. Venturi tee
C. Intake port
D. Bypass relief valve
E. Reservoir
F. Reservoir relief valve

Figure 23. Venturi-tee reservoir pressurization.

8-20. *Jet aircraft reservoir pressurization system.* Figure 24 shows a typical reservoir pressurization system used on most of the modern jet aircraft. Notice that the engine's bleed air (from engine compressor section) first enters the system through a shutoff valve (I). It then passes through a dehydrator unit (A). The dehydrator unit consists of a housing and a cartridge that removes moisture from the air. The moisture content is shown by a small indicator at the top of the cartridge. The unit is so designed that the cartridge can be replaced without disconnecting any of the tubing. Next, the air passes through a filter (B) and a flapper check valve (C) to a pressure regulator. The flapper check valve prevents loss of reservoir pressure when the jet engines are not operating. The pressure regulator (D) controls pressure at all altitudes. When the reservoir pressure reaches its maximum setting, the regulator vents the excess air overboard. When the reservoir is unpressurized, the regulator lets ambient air into the reservoir through a filter (E). The filter prevents dirt from entering the reservoir. After passing through the regulator, the pressurized air enters the top of the reservoir (G). A reservoir relief valve (H) limits maximum pressure if the regulator should fail. A depressurization valve (F) is in the top of the reservoir or in the center of the filler cap. It is used for relieving reservoir pressurization before any servicing or



A. Dehydrator port
B. Filter
C. Check valve
D. Pressure regulator
E. Filter
F. Depressurization valve
G. Reservoir
H. Reservoir relief valve
I. Shutoff valve

Figure 24. Jet aircraft reservoir pressurization.

maintenance is performed. It is a spring loaded, manually operated valve.

8-21. *Suction boost pump pressurization.* A few paragraphs back we told why we must pressurize the suction line to the power pumps. We have also discussed various methods of pressurizing the reservoir. With the suction boost pump system, the reservoir itself is unpressurized, but the fluid to the pump is under pressure.

8-22. Figure 25 illustrates a suction boost pump pressurization system. The suction boost pump is a centrifugal-type pump, driven by an electric or a hydraulic motor. This type of pump supplies a large volume of fluid at low pressure. An example of output would be zero to 20 gallons per minute with a pressure of 70 to 100 psi. This will insure an adequate supply of fluid to the engine-driven pump(s). They cannot possibly produce cavitation when the boost pump is running.

8-23. Downstream from the suction boost pump, we have a pressure switch and a check valve. The pressure switch is connected to a warning light which will illuminate anytime the pressure is too low. The check valve is installed to prevent a reverse flow from the pump to the reservoir when the system is not in operation. By using this type of system, the reservoir filler cap can be removed at any time for servicing.

8-24. **Maintenance of Reservoirs.** There aren't very many problems in maintaining a reservoir, since it is not a very complex unit. Yet, there are a few things that should be observed in the daily care of this component.

8-25. *Servicing reservoirs.* When servicing reservoirs, follow the special instructions on the data plate. Furthermore, adhere strictly to applicable technical order directions. These two sources will give information on servicing instructions, fluid specification, reservoir and system capacity, and position of the various mechanisms during servicing. Remember too much fluid is just as dangerous as not enough fluid. For example, a conventional-type reservoir (as shown in fig. 20) can easily be overfilled. This could cause it to rupture and result in a complete loss of the entire system. Overservicing the piston-type reservoirs, as illustrated in figures 21 and 22, is almost impossible. It is prevented by the automatic operation of the overboard vent lines. These reservoirs are pressure filled with a test stand. Therefore, the reservoir case could be cracked by filling too fast. Finally, always make sure that the fluid is clean and uncontaminated.

8-26. *Removing and replacing reservoirs.* As a pneudraulic mechanic it may be necessary for you to remove and replace a reservoir sometime. If you do, you must follow TO procedures exactly. Only then, can you be sure that you have done the job right. Some general procedures to observe in the removal of a reservoir are as follows:

a. Make sure that there is no pressure in the reservoir.

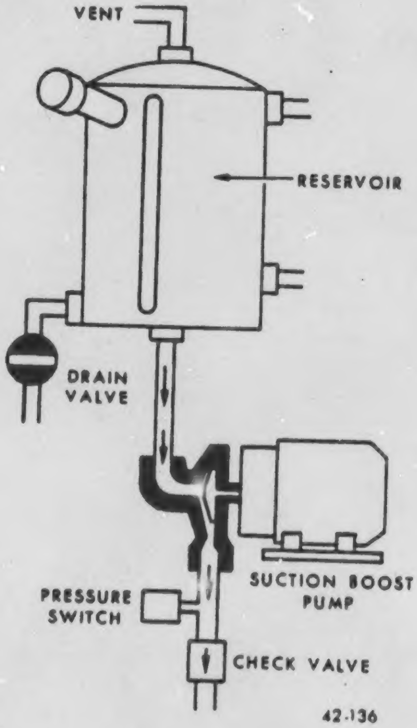
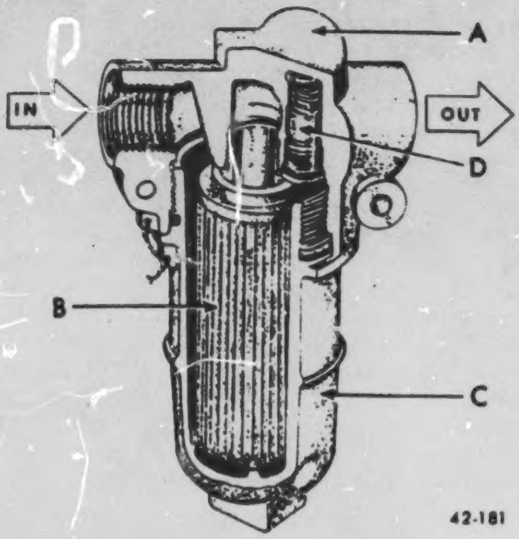


Figure 25. Suction boost pump pressurization.



A. Head
B. Filter element
C. Case
D. Relief valve

Figure 26. Micronic filter.

b. Drain all fluid from the reservoir.

c. Cap and plug all fittings, ports, and lines after unit is removed.

d. Fill a removed piston-type reservoir to about 90 percent fluid capacity with clean hydraulic preservative oil, MIL–H–6083. Then cap or plug all ports to prevent leakage.

General procedures to observe before and during the installation of a reservoir are:

a. Check the reservoir shipping crate for damage. If the crate is damaged, the component may also be damaged.

b. Remove caps and plugs, then drain preservative fluid from piston-type reservoirs.

c. Using new gaskets and O–rings, install necessary fittings. Do not tighten fittings until reservoir is fastened into position and fittings are aligned with connecting lines.

d. Service according to instruction on data plate or existing technical order.

8-27. Observe strictly all warning and caution notes during removal and installation. They concern personal safety, potential damage to equipment, and the necessity for cleanliness.

8-28. We have mentioned the complex nature of many hydraulic units before. Valves, cylinders, poppets, and other parts are so finely machined that even a very minute particle lodged in a unit can cause malfunctions. Therefore, it is most important to keep foreign matter and dirty air from entering the reservoir. Line filters are located at various points through the system to keep the fluid clean. Vent filters are used in the reservoir vent lines to clean the air that enters the reservoir. Also, it is desirable to be able to quickly disconnect a line without loss of fluid.

9. Filters and Quick Disconnects

9-1. The purpose of fluid and air filters is to remove foreign particles from the fluid or air. They are quite similar in construction, but differ in details and materials used. Although a filter is not a complex unit, it is tremendously important. Proper care of the filter is equally important. *Dirty fluid is the deadliest enemy of any hydraulic system!*

9-2. **Pressure and Return Line Filters.** Pressure line and return line filters are generally constructed like the one shown in figure 26. The main parts of this filter are: case, head, filter element, and relief valve. The case (C) contains the element (B). The head (A) screws onto the case and has an "in" port, "out" port, and relief valve (D). The normal flow of fluid through this filter is in through the "in" port. The fluid fills the case around the outside of the element. It then flows through the element to the inner chamber, and out through the "out" port.

9-3. This filter element is made of a specially treated cellulose paper. It is commonly called a *micronic-type* element. However, the element could have been of sintered bronze (metal powder pressed into shapes under heat). It could be a woven wire, a one-piece corrugated wire mesh, or a corrugated sintered stainless steel mesh. Also, a magnetic-type element can be used with any of the elements mentioned above. This is called a dual-element-type filter. The elements listed above generally have a minimum rating of 10 micron pore size. The maximum rating is 25 microns (1 micron being equal to 0.00004 of an inch). All of these filters incorporate a relief valve, set anywhere from 50 to 100 psid. Its purpose is to bypass unfiltered fluid if the filter becomes clogged. The pressure of the blocked fluid will force open the relief valve.

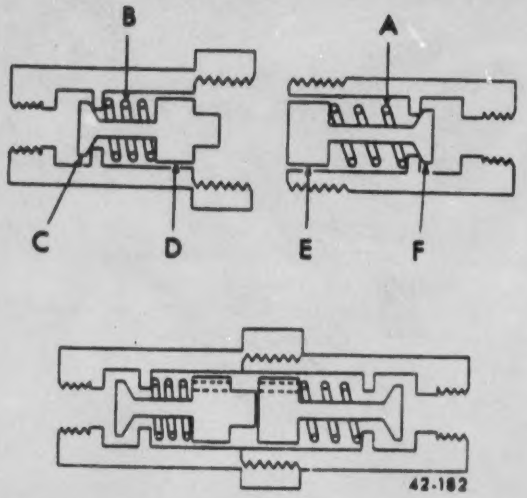
9-4. **In-line Filter Restrictors.** Another type of filter that is used in hydraulic subsystems is the in-line filter restrictor. This type of filter resembles a large check valve. It contains two wire mesh finger screens that are installed on either side of the fixed orifice plate. Unlike the pressure and return line filters, in-line filters do not incorporate a relief valve. They could cause the subsystem in which they are located to fail if they should become clogged.

9-5. Maintenance of Filters. Maintenance of filters is relatively easy. It mainly involves cleaning the filter and element or cleaning the filter and then replacing the element. Filters using the micronic-type element should have the element replaced periodically. The time is according to instructions appearing in the applicable TO publications. Since reservoir filters are of the micronic type, they must also be periodically changed or cleaned. On filters using other than the micronic-type element, cleaning the filter and element is usually all that is necessary. However, the element should be inspected very closely to insure that it is completely undamaged. The methods and materials used in cleaning all filters are too numerous to mention. Consult the applicable technical order publication for this information.

9-6. Some hydraulic filters have been equipped with an indicator pin that will visually indicate a clogged element. When this pin protrudes from the filter housing, the element should be removed and cleaned; also, the fluid downstream of the filter should be checked for contamination and flushed if required. Too, all remaining filters should be checked for contamination and cleaned (if required) to determine the cause of contamination. In addition, pressure, proof, and flow tests of filters should be completed as outlined in the applicable TOs.

9-7. Line-Disconnect or Quick-Disconnect Valves. These valves are installed in hydraulic lines to prevent loss of fluid when you remove units. Such valves are installed in the pressure and suction lines of the system just in front of and immediately behind the power pump. These valves can also be used in other ways than just for unit replacement. A power pump can be disconnected from the system and a hydraulic test stand connected in its place. These valve units consist of two interconnecting sections coupled together by a nut when installed in the system. Each valve section has a piston and poppet assembly. These are spring loaded to the CLOSED position when the unit is disconnected.

9-8. The top illustration of figure 27 shows the valve in the LINE-DISCONNECTED position. The two springs (A and B) hold both poppets (C and F) in the CLOSED position as shown. This prevents loss of fluid through the disconnected line. The bottom illustration of figure 27 shows the valve in the LINE-CONNECTED position. When the valve is being connected, the coupling nut draws the two sections together. The extension (D or E) on one of the pistons forces the opposite piston back against its spring. This action moves the poppet off its seat and permits the fluid to flow through that section of the valve. As the nut is drawn up tighter, one piston hits a stop; now the other piston moves back against its spring and, in turn, allows fluid to flow. Thus, fluid is allowed to continue through the valve and on through the system.



A. Spring
B. Spring
C. Poppet
D. Piston
E. Piston
F. Poppet

Figure 27. Line-disconnect valve.

9-9. Bear in mind that the above disconnect valve is only one of the many types presently used. Although all line-disconnect valves operate on the same principle, the details will vary. Each manufacturer has his own design features.

9-10. A very important factor in the use of the line-disconnect valve is its proper connection. Hydraulic pumps can be seriously damaged if the line disconnects are not properly connected. For instance, if they should block the free flow of hydraulic fluid through the system. If you are in doubt about the line disconnect's operation, consult the aircraft's appropriate TO.

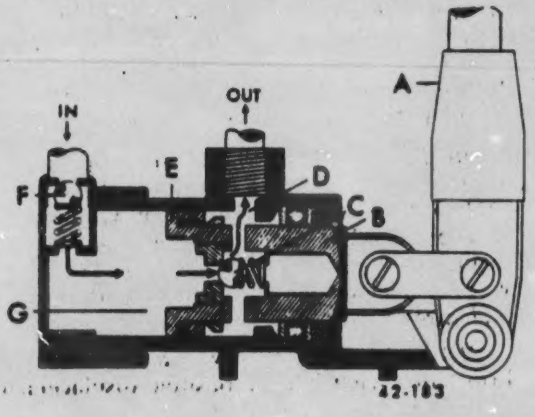
9-11. The extent of maintenance you will perform on a quick disconnect valve is very limited. The internal parts of this type valve are precision built and factory assembled. They are made to very close tolerances. Therefore, no attempt should be made to disassemble or replace internal parts in either coupling half. However, you may replace the entire assembly and some of the external parts. For example, you may replace coupling halves, lock-springs, union nuts, and dust caps. When replacing the assembly or any of the parts, follow the instructions in the applicable TO.

10. Hydraulic Pumps

10-1. Like the human heart, the hydraulic pump is the source of fluid flow and pressure. Hand pumps are simple devices for occasional use. Power pumps are either driven by engine or electric motor. Those used today are complex devices.

10-2. **Hand Pumps.** The hand pump serves as a substitute for the power pump during emergencies in flight. It is a source of power for ground check of the hydraulic system when the aircraft is on the ground.

10-3. *Construction and operation.* Hand pumps are reciprocating piston-type pumps that are either single- or double-action. Most of them, however, are the double-acting type. These deliver fluid under pressure on both the fore and aft strokes of the piston. Figure 28 illustrates the double-action, piston-displacement-type pump. This unit consists of a cylinder assembly, a piston (E) containing a builtin check valve (C). The piston separates the right chamber (D) from the left chamber (G). It has a large piston rod (B), an operating handle (A), and a check valve (F) at the "in" port. Some pumps of this type use a one-way seal in place of the piston head check valve (C). This seal allows flow in one direction and prevents flow in the opposite. The seal is located between the piston and cylinder wall. It works like the leather in an air or water pump—like a bicycle pump. The left chamber (G) is larger than the right chamber surrounding the piston rod (B). This causes fluid flow when the piston (E) moves to the right. Almost all modern aircraft use the double action displacement type pump. We will not go into the operation of the hand pump here. You learned all that in the first chapter of this volume. You may review it though by turning back to paragraph 7-21.



A. Pump handle
B. Piston rod
C. Check valve
D. Right chamber
E. Piston
F. Inlet check valve
G. Left chamber

Figure 28. · Double-acting displacement-type hand pump.

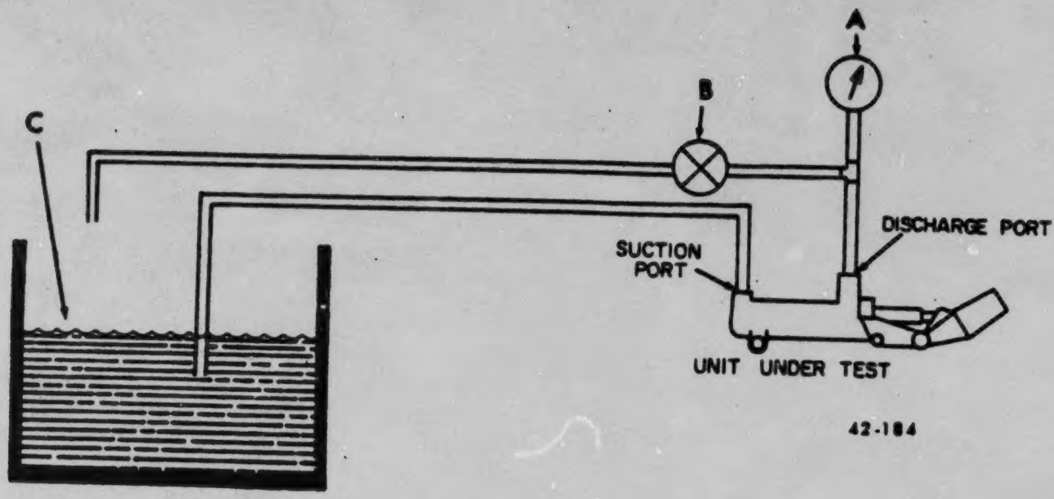
10-4. Every piece of equipment, no matter how simple, can malfunction. The hand pump is no exception. However, since it is only operated at short intervals, malfunctions do not occur too often. They can happen, though, and you can determine the cause if you understand its operation.

10-5. Failure of either check valve (C or F) will cause the hand pump to become completely inoperative. However, installing a third check valve in the pressure (out) line is a great improvement. Now, one of the check valves or the piston head seal could fail. Yet, the pump could still produce pressure on at least one stroke of the cycle. This third check valve prevents normal system pressure from reaching the hand pump during normal system operation. It will also aid the mechanic in determining hand pump failure. If check valve (F) in the inlet port leaks, the pump will develop pressure only on the piston "extension" stroke. If check valve (C) in the piston rod or the piston head seal leaks, the pump will develop pressure only on the piston "retraction" stroke. If the pressure (out) line check valve leaks, there will be no immediate indication of it. In this case the pump will still develop pressure on both strokes. Now that we know some hand pump malfunctions, we can discuss what should be done to maintain hand pumps.

10-6. *Maintenance.* Basically the care of hand pumps consists of disassembly, inspection, reassembly, and testing. After disassembly, thoroughly clean all parts. Carefully inspect them for nicks, cracks, scratches, and corrosion. Also, inspect threaded surfaces for damaged threads, piston shaft for distortion, and springs for distortion. Also check valve balls (poppets) for proper seating. Look for anything that can cause pump failure.

10-7. Replace all defective parts that are not repairable at each overhaul. The same is true for all kitted parts (parts ordered in a kit). Cure-dated parts (natural or synthetic rubber items) must be replaced any time the pump is disassembled. Minor scratches and corrosion may be removed or polished out by using a specified type of crocus cloth. If necessary, clean internal threads with the correct size tap. Next, clean all external threads by filing or with the proper size die.

10-8. Before reassembly, all interal parts should be coated with clean hydraulic fluid used in the system. After the pump has been reassembled, test it for proof pressure and



A. Gage
B. Shutoff valve
C. Reservoir

Figure 29. Hand pump test circuit.

leakage. Figure 29 shows the setup for testing the hand pump. Basically it consists of a gage (A), shutoff valve (B), reservoir (C), and the necessary tubing runs. With the pump connected, you first pump fluid through the circuit with the shutoff valve (B) open. This bleeds all air from the system. Next, you close the shutoff valve and operate the pump to obtain the required proof pressure. Proof pressure is approximately 1 1/2 times normal operating pressure. You should control the strokes so that the final stroke will leave the piston in the retracted position. Pressure should be maintained for a specified time limit (usually 2 to 5 minutes). Repeat the preceding step. This time, control the strokes so that the final stroke will leave the piston in the extended position.

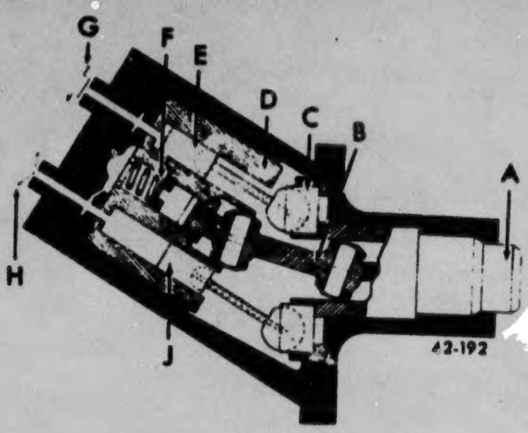
10-9. For the leakage test, use the pump to pressurize the circuit to the normal operating pressure. (The shutoff valve (B) is closed during this check.) The pressure must hold for a specified period of time (approximately 2 minutes). There should be no piston creep, and the pressure drop should not exceed the specified amount (usually 50 to 100 psi).

10-10. After completion of testing, relieve the pressure and remove the pump from the test circuit. Drain the pump to the drip point. Then refill it with the specified preservative fluid to about 90 percent of its capacity. Plug all ports and closures and mark the rubber parts' cure date on the pump. Instructions for this are given in the applicable TO.

10-11. **Constant-Volume Power Pumps.** The primary energizing unit of the hydraulic system is the power pump. It is the unit that normally delivers hydraulic fluid under pressure to the actuators. It may be driven either by an electric motor, turbine unit, or by the aircraft engine. The power pump used in a modern hydraulic system will be of a piston type. This type may be further divided according to method of operation and volume output. Most all hydraulic system pumps have common constructional features. Power pumps are designed so that they can run satisfactorily in either direction of rotation. They are designed to run at a rated speed of 3750 rpm, or about 1 1/2 times engine crankshaft speed. Gear type pumps previously were used in hydraulic systems. An example of a gear type pump is the oil pump on your automobile.

10-12. the drive shafts of all pumps have a shear section. This is a thinned portion of the shaft. If the pump seizes, the shaft will break at this point, thus preventing damage to the engine. (A permanently attached data plate gives the manufacturer's name, the part number, and direction of rotation.)

10-13. One of the power pumps used in hydraulic systems is the positive displacement piston type. Each rotation of this type of pump forces a *fixed* amount of fluid out the discharge port. The other type of pump used is the variable-volume piston pump. This type of pump will vary the volume of discharge to meet the momentary needs of the system.



A. Drive shaft
B. Universal link
C. Point of attachment
D. Cylinder block
E. Piston
F. Foot valve
G. Pressure port
H. Intake port
J. Piston

Figure 30. Constant-volume piston-type pump.

10-14. Constant-volume piston-type pumps put out a constant flow of fluid for any given rpm. The pistons, usually seven or nine in number, are fastened by universal linkage to the drive shaft. See figure 30. The universal link (B) in the center drives the cylinder block (D). This block is held at an angle to the drive shaft (A) by the housing. Everything within the housing rotates with the drive shaft. As the piston (J) moves to the lower position, its cylinder fills with fluid. When it rotates to the upper position (E), its movement will force fluid out of the pressure port (G). As it again moves to the lower position, it again draws in fluid through the suction port (H). Since there are always pistons somewhere between the upper and lower position, constant intake and output of fluid results. Pumps are available with different angles between the drive shaft and cylinder block; a large angle provides more volume output per revolution, because the larger angle increases the piston stroke.

10-15. As the drive shaft (A) is rotated, it rotates the cylinder block (D) and piston assemblies. Notice that all pistons are always the same distance from their points of attachments (C) on the drive shaft. Although the pistons appear to move within the cylinders, it is the cylinders that move back and forth around the pistons as the block and piston assembly rotates. However, it is customary for a piston to move within a cylinder. Since this appears to be happening, we will describe the pumping action of the pump in these terms.

10-16. To understand the operation, follow a piston through one complete revolution. The piston is at the top of its cylinder. It has just completed its pressure stroke and is ready to begin its intake stroke. As the block starts to rotate from this point, the piston becomes aligned with the intake port. When the block has turned one-half of a revolution, the piston reaches the bottom of the cylinder. The cylinder space formerly occupied by the piston is now full of fluid.

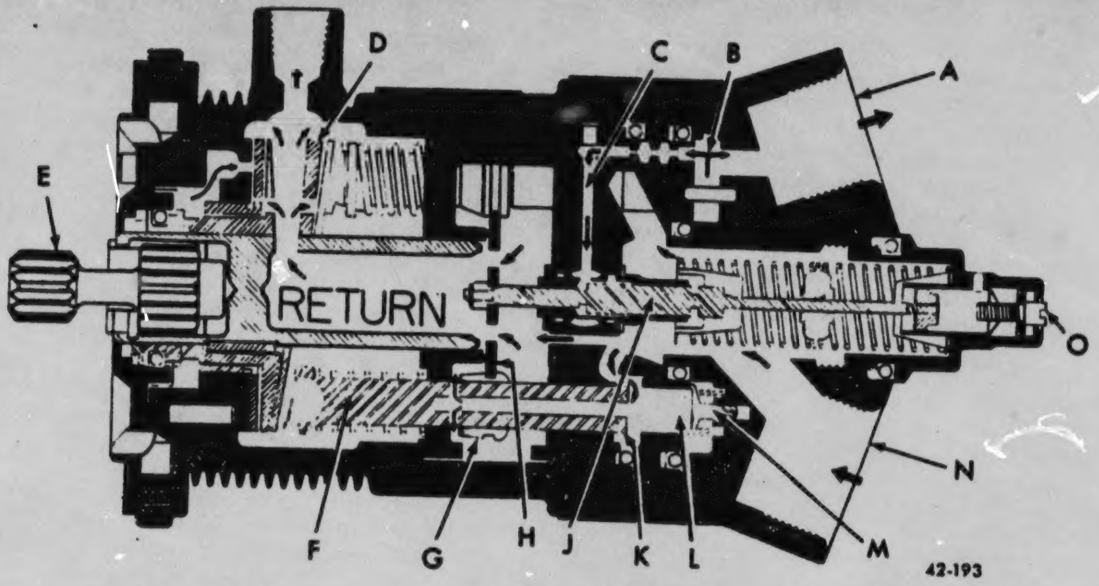
10-17. As the block continues to rotate, the piston becomes aligned with the outlet port slot. Thus, when it has moved through the last 180° of rotation, it exhausts all fluid from the cylinder. At this point, the piston is again ready to make another cycle.There are several pistons operating as described above. The cylinder block and piston assembly rotate rapidly. Therefore, there will always be a positive flow of fluid through the outlet port.

10-18. The piston-type pump uses case pressure for cooling and lubrication. Fluid seeps by the pistons in the cylinder block and fills all the space inside the pump. This fluid cannot escape through the drive end of the pump because of a seal placed around the drive shaft. Excess case pressure within the housing is routed back to the intake side of the pump. This is done through a relief valve called a *foot valve.* (See fig. 30, item F.) This valve prevents the case pressure from rising above approximately 15 psi. Notice the drilled passageways through the universal link rods. These help to keep the rod ball ends lubricated.

10-19. Figure 30 shows the foot valve (F) located inside the bearing around which the cylinder block rotates. Other models have the valve in the head together with the intake and outlet ports. Some of the newer models have two foot valves, both located in the head. The direction the accessory drive rotates determines the direction of pump action. An arrow on the pump head indicates the direction of rotation for which the pump is set up. The direction of rotation of a piston-type with one foot valve can be reversed. To do so, remove the cylinder block head, rotate it 180°, and reinstall. Leave the suction and pressure attachments as they were. This, in effect, reverses the intake and outlet port slots mentioned in paragraphs 10–16 and 10–17. For the models with two foot valves, it is not necessary to rotate the head. Simply interchange the suction and pressure line connections.

10-20. The power pumps discussed thus far have been the constant-displacement type; that is, for any given rpm the volume output is constant. However, the other version of the piston-type pump is the variable-volume type.

10-21. **Variable-Volume Pumps.** The variable-volume pumps have some advantages.

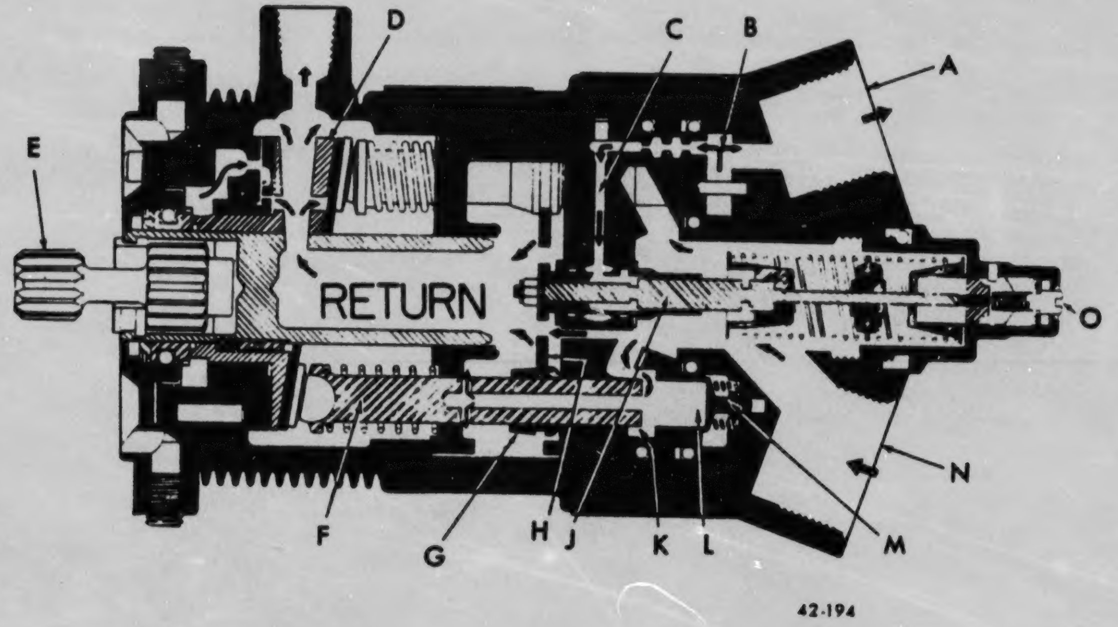

D
C
B
A
E
RETURN
O
N
F
G
H
J
K
L
M
42-193

A. Out port
B. Pressure chamber
C. Pressure passageway
D. Cam
E. Drive shaft

F. Piston
G. Sleeve
H. Spider
J. Compensator

K. Annalus
L. Cylinder
M. Check valve
N. In port
O. Adjusting screw

Figure 31. Stratopower pump, demand type (full flow).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A. Out port
B. Pressure chamber
C. Pressure passageway
D. Cam
E. Drive shaft

F. Piston
G. Sleeve
H. Spider
J. Compensator

K. Annalus
L. Cylinder
M. Check port
N. In port
O. Adjusting screw

Figure 32. Stratopower pump, demand flow (zero flow).

One is that its use does away with the need for a pressure regulator or unloading valve. Integral flow control valves regulate the pressure according to the demands made of the system. A second advantage is that this type pump provides a more stable pressure. Pressure surges are reduced. Accumulators are not necessary with systems using variable-volume pumps to smooth out surges. However, they are retained to aid the pump at those times when peak loads occur.

10-22. The first type of variable-volume pump that we will discuss is the Stratopower pump. These pumps are available for operating pressures ranging from 1000 to 3000 psi.

10-23. *Stratopower pumps (demand principle).* As shown in figure 31, the drive shaft (E) rotates the cam (D). This cam causes the nine spring-loaded pistons (F) to move back and forth in their cylinders. The cylinders are in a stationary cylinder block. Creep plates (look like washers in this figure) on either side of the cam provide for cooler operation. They also give more even wear on the cam. In operation, each piston is compressed into and released from the cylinder, once for each revolution of the cam. The pistons are held in contact with the creep plate by piston springs. The springs also return the pistons after each forward or power stroke. Each piston has a half-ball bearing surface which acts like a universal linkage. The flat side contacts the creep plate during all angle changes with the least wear.

10-24. The pistons (F) have fairly large hollow centers, connected with cross-drilled holes. Each piston has a sleeve (G) around it. The sleeves are attached to a spider (H); the spider is attached to the compensator (J), or volume control valve. An increase of pressure moves the compensator (J) to the right. A decrease of pressure allows it to move to the left because of the valve spring tension. As the pistons travel to the left, fluid is drawn from the "in" port (N). It passes through the open center of the cylinder block, and then into the cylinders (L). At this point, hydraulic fluid will fill the center of the pistons. Some fluid will continue to flow out through the cross-drilled holes and on to the pump's return port. The return port is on the drive end of the pump. As the pistons are forced to the right by the cam (D), the cross-drilled hole of each piston is blocked off by its sleeve.

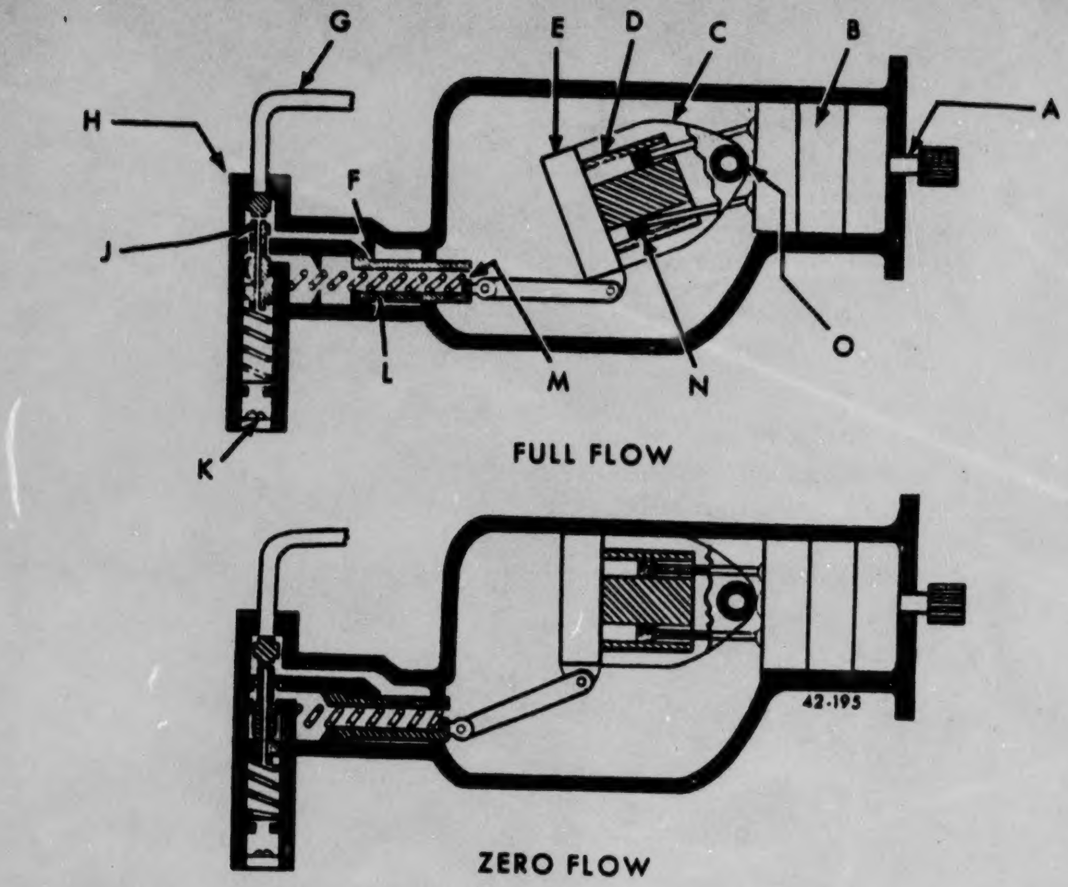
10-25. About the time the cross-drilled passage is blocked off, the supply annulus (K) that surrounds the cylinder is also blocked off. An annulus is a ridgelike or a groovelike ring. It is located around a shaft or around the inside of a hole. It provides a route for fluid flow. This, in turn, traps the fluid in the piston and cylinder. As the piston continues on to the right, pressure builds up against the check valve (M). Fluid under pressure goes out the check valve into the pressure chamber (B) and through the "out" port (A). When the piston moves as far right as possible, the cycle starts all over again.

10-26. This cycle is the same for all nine pistons. As pressure rises in the pressure outlet line, it is also felt in the passageway (C). This pressure acts on the compensator piston (J) forcing it to the right. This compresses the spring and carries the spider and sleeves /(H and G) with it. The more the sleeves move to the right, the farther each piston will travel before the cross-drilled passage is covered. (See fig. 32.) This means that less fluid is trapped by the right end of the popiston for output to the pressure manifold. The maximum setting of the compensator is when it is all the way to the right. Then the output to the pressure manifold drops to zero. (See fig. 32.) All intake of the pump then goes out the return port. Rotation of the cam draws fluid through the pump for cooling and lubrication. There is always fluid being pumped through the "in" port. But, fluid will not be pumped through the "out" port until system pressure drops low enough to demand it.

10-27. This pump can also be rotated in either direction with no changes. Always connect the proper lines to the ports marked IN, OUT, and RES. The use of this type of pump also eliminates the need for a pressure regulator. The compensator serves nearly the same purpose. Adjustment of maximum pressure may be made by turning the adjusting screw (O). Turning it *clockwise increases*, and *counterclockwise decreases.*

10-28. Various other types of variable-volume pumps operate on the *stroke-reduction* principle instead of the *demand* principle. However, we will discuss only two types, the Vickers and the Kellogg.

10-29. *Vickers stroke-reduction-type pumps.* These have many parts similar to the constant volume piston-type pumps. Also, the drive shaft (A), pistons (N), and cylinder block (D) all rotate in the stroke-reduction-type pump. (See fig. 33.) They are supported by the bearing (B). The main difference between this pump and the constant-volume pump is the angle between the drive shaft and the cylinder block. In the constant-volume pump, this angle is fixed, while the angle of the variable-volume pump varies automatically. Its angle depends upon the pressure-volume demands of the system.



A. Drive shaft
B. Bearings
C. Yoke
D. Cylinder block
E. Valve plate
F. Passageway
G. Connecting line

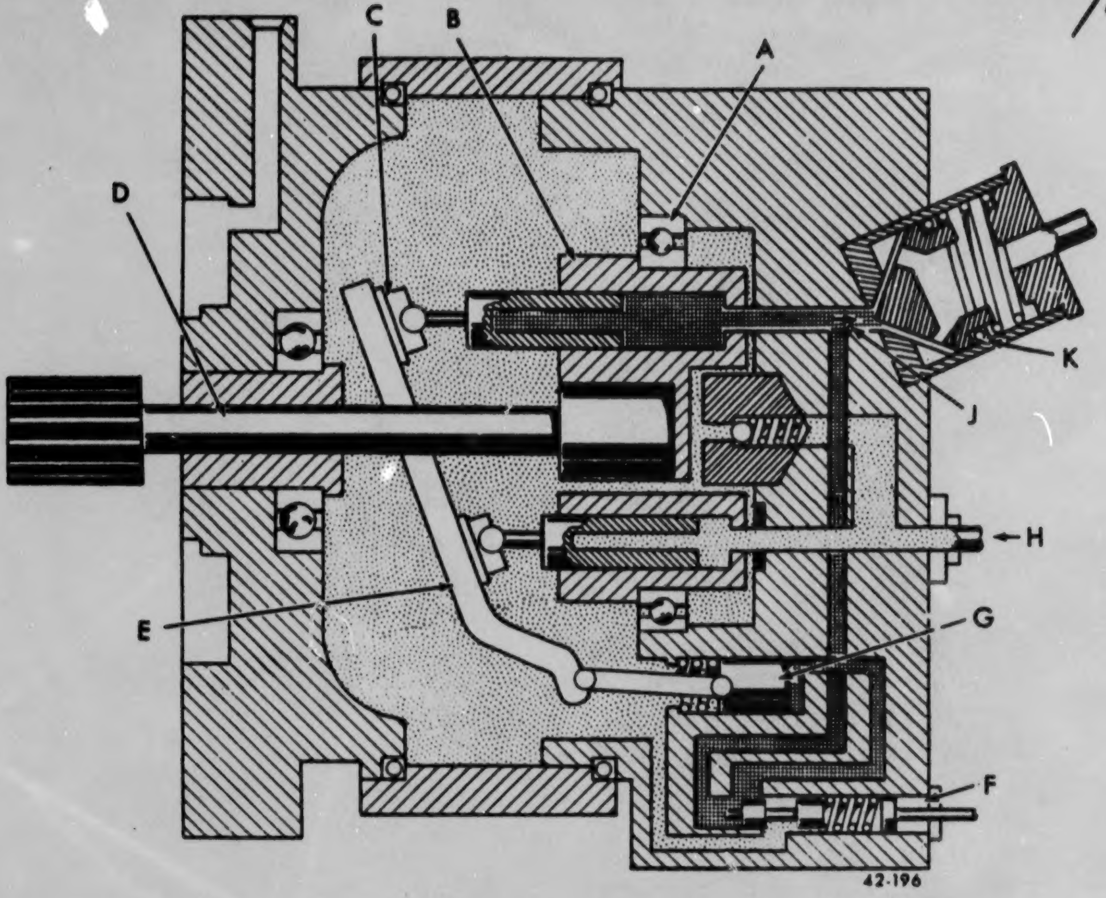
H. Pressure control valve
J. Pilot valve
K. Adjusting screw
L. Pressure control piston
M. Hollow center (control piston)
N. Piston
O. Pivot pin

Figure [illegible]. Variable-volume pump, stroke reduction type.

10-30. A yoke (C) contains the cylinder block, which swivels around the pivot pin (O). The pivot pin is hollow and designed to provide a passage for the pump's inlet and outlet fluid. Before the pump builds up any pressure, the yoke is held in the position shown in figure 33, FULL FLOW. The spring in the pressure control piston (L) holds it there. When outlet pressure is at maximum, the yoke (C) is held in position shown in figure 33, ZERO FLOW.

10-31. We start with zero pressure in the system. The cylinder block and yoke are in the extreme angle position, as shown in figure 33, FULL FLOW. As the pump builds up system pressure through the outlet port (0), it acts on the pressure control valve (H). System pressure entering the connecting line (G) acts on the pilot valve (J). It pushes this valve down against the spring towards the ZERO FLOW position (fig. 33). This opens the passageway (F), sending pressure against the rod side of the control piston (L). As the position moves to the left, it compresses its spring. This force, transmitted through the valve plate (E), causes the yoke (C) to swivel upward. The cylinder block moves toward a zero angle with the drive shaft ZERO FLOW. If it reaches the extreme ZERO FLOW point the fluid output from the pressure port is zero. This is because the pump pistons have no stroke in the cylinder block. They simply rotate with the cylinder block without moving back and forth.

10-32. As the pressure in the system starts to drop, its force on the pilot valve (J) is reduced. When this happens, the spring under the pilot valve moves it upward. This reduces the



A. Roller bearing
B. Cylinder barrel
C. Piston shoes and plate
D. Drive shaft
F. Compensator valve
E. Cam plate
G. Stroking piston
H Inlet
J. Outlet
K. Check valve

Figure 34. Kellog pump

opening to the passageway (F) and cuts down the pressure on the pressure control piston (L). Its spring pushes this piston to the right. Now the yoke (C) swivels downward thereby causing the stroke of the pistons to increase. The pressure and volume output again start to increase until the system's demands are met. Thus, the action of the control valve (H) stabilizes the position of the control block (D). It adjusts its angle to meet the system demands. Notice the hollow center of the control piston (M) is vented to the inside of the case. Fluid trapped inside the piston can excape to the case. A foot valve (not shown) prevents case pressure from becoming too high. Direction of rotation of this pump cannot be changed. Therefore, you must be sure to check the direction arrow on the mounting flange before installing. The maximum pressure is adjusted by turning the adjusting screw (K) to increase or decrease it. An internal relief valve prevents damage in case the pressure control valve fails to function properly.

10-33. *Kellogg stroke-reduction-type pumps.* Figure 34 shows a schematic of the Kellogg pump. This pump delivers 15 gallons per minute (gpm) at a minimum pump speed of 4200 rpm. At a maximum pump speed of 7300 rpm, it delivers 28 gpm. The pump is made up of two major component groups. They are the rotating group and the pressure-compensating group. The rotating group consists of the drive shaft (D), the cylinder barrel (B), nine pistons, and the piston shoes and locking plate (C). The pressure-compensating group consists of a compensator valve (F), stroking piston (G), and a cam plate (E).

10-34. The cylinder barrel (B) has a fluid inlet annulus (slot) in its face to supply the cylinders. It is long enough to serve during the intake portion of one revolution. An outlet annulus serves the discharge portion of one revolution. The barrel is supported in the housing by a roller bearing (A). The drive shaft (D) passes through, but does not touch, the inclined cam plate (E) to rotate the cylinder barrel (B) unit. Pistons, of the rotating group, are actuated by tilting nonrotating cam plate (E). The contact is a universal action. It consists of hydraulically balanced shoes and locking plate (C). The length of piston stroke is determined by the angle setting of the cam plate. Maximum pump output requires a high angle; zero pump output requires a flat angle setting.

10-35. The lower piston in figure 34 is shown near the beginning of the intake stroke. As the cylinder unit is rotated, the piston moves to the left in its individual cylinder. The face port of this cylinder is aligned with the fluid inlet annulus for nearly one-half of a revolution. Hydraulic fluid is sucked into the cylinder as the piston is withdrawn. The top piston in figure 34 is fully withdrawn and has just passed the end of the inlet annulus. This annulus is connected to the fluid inlet (H). Further rotation forces the piston to the right. The cylinder will then be aligned with the outlet annulus during the discharge stroke. This stroke lasts until the cylinder and piston reach the bottom position in figure 34. The outlet annulus is connected to the outlet port (J) and the compensator valve (F).

10-36. We have described the intake and discharge strokes of one piston during 360° of cylinder rotation. At the same time, there are eight other pistons on the intake and discharge strokes, all doing the same thing. Their pumping action continues until the fluid needs of the system are satisfied. For instance, when a subsystem actuator completes its travel, the need for pump output is reduced to zero. The pump senses the end of the actuator travel because the unused output causes a sudden increase in discharge pressure. As this pressure reaches the setting of the compensator valve (F) it pushes the valve to the right. The pressure then can push on to the stroking piston (G). There it causes the stroking piston to move to the left and decreases the angle of the cam plate (E). Thus it decreases the effective length of the piston stroke and the volume of fluid delivered to the system. In actual operation, the cam plate assumes various angles to maintain the systems proper pressure. It will meet all fluid demand conditions within the rating of the pump. A pump check valve (K) is installed in the pump outlet line. It prevents return flow into the pump during operation of the system with a portable test stand. Reverse flow of hydraulic fluid would motorize the pump.

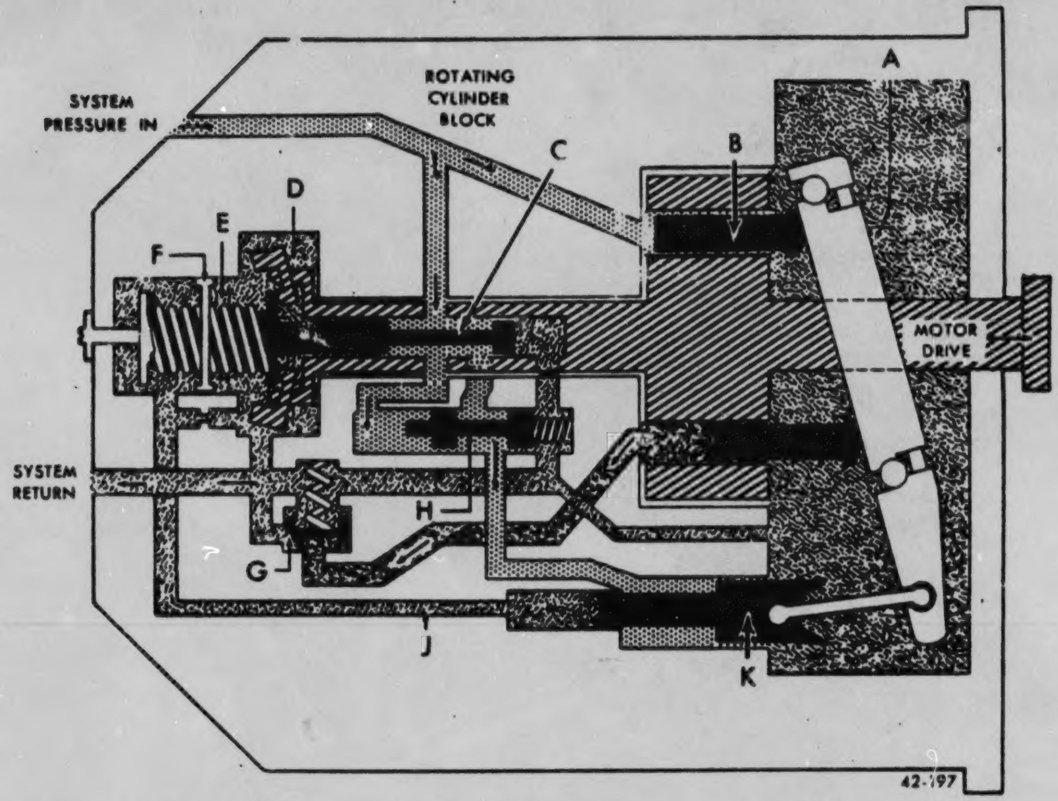
10-37. **Maintenance of Pumps.** The repair and overhaul of hydraulic pumps is done at depots. This work requires use of special tools and complex test equipment that many bases do not have. However, if you have a test stand, you should bench check every pump before you install it on an aircraft. The bench check procedures that vary with every pump are very exacting. Therefore, we will not give them here; instead, follow the TO when you make a bench check.

11. Hydraulic Motors

11-1. Since this chapter pertains to system supply units, the discussion of motors may seem out of place. Yet, motors operate on the same principle as pumps, but in reverse; therefore, the most logical place to discuss motors is in this chapter.

11-2. The hydraulic motor shown in figure 35 is a variable-displacement, axial-piston, rotating-cylinder-block unit. It delivers a minimum of 16.6 horsepower at 8000 rpm. This particular motor is used to drive an ac-dc generator at a constant rpm. An ac generator or alternator must put out the same number of cycles per second, under all load conditions. This fact requires the use of a very sensitive flyweight type of governor on the motor. For components where the rpm is not critical, a constant-displacement-type hydraulic motor would likely be used. The rpm of this latter type motor would probably be controlled by constant flow valves. Such a valve would be connected in either the inlet or outlet lines, or both.

11-3. **Operation.** If you understand the operation of the motor in figure 35, you should have little trouble with others. Now turn to the figure. When the hydraulic system is pressurized, fluid pressure is exerted on the pistons (B) of the cylinder block. It also must go to the closed starting valve (H) of the motor. Although normal system pressure will sustain cylinder and generator rotation, the rotation must first be started. Starting is accomplished by the starting valve (H). When system pressure builds up to 1800 to 2200 psi, the starting valve is moved to the right as shown. This action aligns a passage which permits fluid under pressure to move the control piston (K). The control piston moves the bottom of the wobbler plate (A) to the right with sudden force. Movement of the wobbler gives kick to the pistons (B) to give the cylinder block an initial



A. Wobbler plate
B. Pistons (upper - lower)
C. Governor control valve
D. Governor flyweights
E. Governor spring
F. Preact piston
G. Back pressure valve
H. Starting valve
J. Feedback line
K. Control piston

Figure 35. Hydraulic drive motor.

spin. Thereafter, system pressure maintains rotation of the cylinder block.

11-4. As hydraulic pressure continues to increase, motor speed will increase. As the rotational speed increases, the governor flyweights (D) begin to pivot outward. This action causes the governor control valve (C) to be moved proportionately to the left. This movement gradually blocks the pressure to the control piston (K). When the passage is completely blocked, pressure is no longer exerted on the control piston, and the motor ceases to increase speed. This is referred to as an "on speed" condition.

11-5. The load imposed on the motor varies with the electrical load on the generator. To meet the changing demands, the motor must vary its torque to maintain its normal operating speed. For instance, let us assume that the generator load is reduced and that the motor tends to overspeed. This causes the governor flyweights (D) to move outward and pull the governor control valve (C) slightly to the left. Movement to the left from the blocked position, vents the control piston (K) passage to return system pressure. This reduces the force acting on piston (K). Now, system pressure acting on the upper pistons (B) is greater than the return system pressure on the control piston (K). This will let the upper pistons (B), in the rotating cylinder block move the wobbler plate (A) toward the right. This movement starts to reduce the angle of the wobbler plate (A). This, in turn, reduces the torque output and consequently the speed of the motor. Movement of the wobbler plate also momentarily activates the preact piston (F) of the flyweight governor. This prevents overtravel of the governor control valve (C) and hastens the motor's response to changes in load. The preact piston acts when the wobbler plate (A) moves to the right, and the control piston (K) moves to the left. This action forces fluid in the feedback line (J) into the chamber on the left side of the preact piston

(F). When fluid moves into this chamber, the preact piston (F) moves to the right to increase tension on the governor spring (E). It also opposes the governor control valve (C) movement to the left. Then, motor speed decreases, and the fluid in the preact piston chamber bleeds off through the restrictor bleed. The governor control piston moves back to the right to block the control piston passage and holds the wobbler plate (A) in its new position. This whole series of events occurs almost instantly to match torque requirement with the imposed load.

11-6. A back pressure valve (G) is installed in the lower piston's discharge line. The purpose is to prevent the lower piston from "floating" and chattering. If this valve were not in the return line, return pressure would exist on both sides of the lower pistons. Under this condition, the pistons would tend to float. The back pressure valve puts 100 psi over return pressure load on the back side of the lower pistons. This load holds them against the wobbler plate (A) and prevents possible chattering.

11-7. It takes 3 gallons of fluid per minute to run the motor with no generator load and 14 gallons per minute at full load.

11-8. **Maintenance.** The rpm of the motor can be adjusted by turning the screw on the back of the governor. If the generator frequency is low, you must turn the governor adjustment screw clockwise. (This direction of adjustment rule does not apply to all governor-controlled hydraulic motors.)

11-9. The depth of maintenance you will perform on hydraulic motors depends on the equipment you have. Like that of hydraulic pumps, the repair and overhaul of hydraulic motors is depot level work. It involves the use of special and complex test equipment. Normally, you must perform a bench check on hydraulic motors before installing them on aircraft. Carefully follow the TO procedures laid out for this operational test.

Pressure-Regulating, Limiting and Controlling Devices

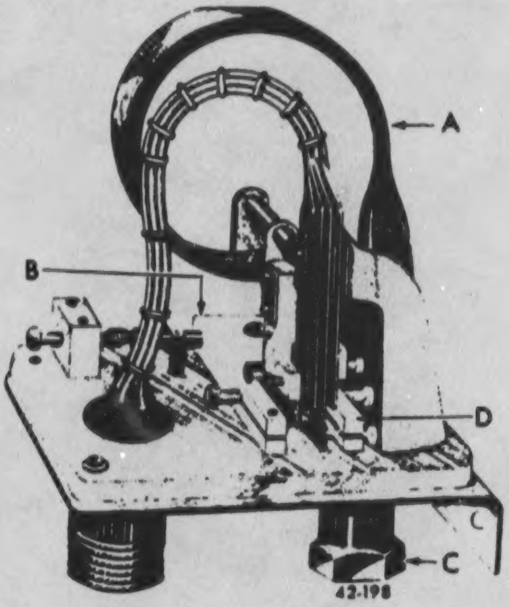
WE HAVE SEEN how the compensator on the variable-volume pump controls the pressure in the hydraulic system. But, with the continuous output of the *constant-volume* pump, we need some unit to regulate the pressure. The type of unit used depends on the manner in which the pump is driven. If the pump is electrically driven, a pressure-operated off-on switch is used on the pump motor. On the other hand, if the pump is engine driven, a pressure regulator is used to maintain the desired system pressure.

2. Besides pressure switches and pressure regulators, other units help control the pressure in the system. For example, there are relief valves, purge valves, and the pressure-reducing valves. Let's start our discussion with pressure switches and regulators.

12. Hydraulic Pressure Switches and Regulators

12-1. **Pressure Switches.** Pressure switches are used in hydraulic systems with electrically driven pumps to maintain system pressure within set limits. At the proper pressure limit setting, the pressure switch opens the pump motor circuit, causing the pump to stop. As pressure drops to the lower limit, the switch closes the circuit to start the pump running again. Pressure switches are also used in hydraulic systems to control operation of warning and protective devices. At a set minimum pressure, the switch may turn on a light to warn the pilot (or operator of a test stand) of low pressure. It may even turn off a pump to avoid exhausting reservoir fluid through a broken line. Pressure switches come in various types. For example, there is the Bourdon tube type, the piston type, and the diaphragm type. Since the Bourdon tube type is the most complicated in operation, we will discuss it in detail.

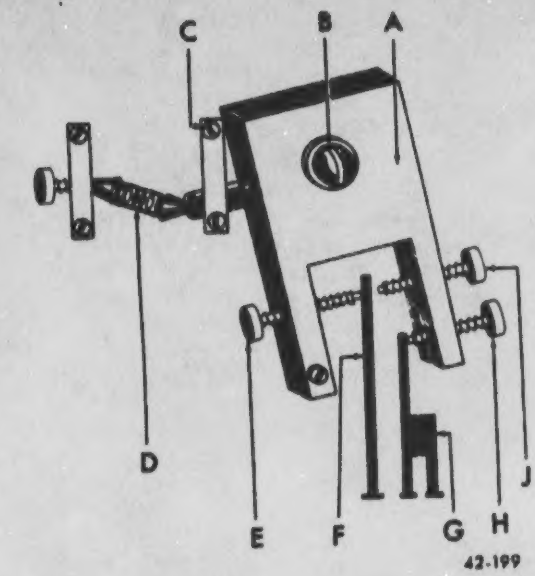
12-2. Figure 36 shows a typical Bourdon tube type of pressure switch used to turn a pump motor off and on. The Bourdon tube is used as a pressure-measuring device in hydraulics because of its ruggedness. Its normal unpressurized shape is a flat hollow coil as shown in the figure (A). As hydraulic pressure is applied through the connection (C), the tube starts to straighten out. A flexible steel finger, attached to the small end of the tube, moves outward as the tube (A) uncoils. This finger presses against the toggle plate (B) until the desired system pressure is reached. At that time, it causes the toggle to pivot rapidly, thereby opening the contact points. This breaks the electrical circuit to the motor.



A. Bourdon tube
B. Toggle plate
C. Hydraulic fluid connection
D. Toggle plate opposite inner surface

Figure 36. Bourdon tube pressure switch.

12-3. When the pump motor is inoperative, no fluid will enter the system. However, our system fluid will remain under pressure until an actuator is operated; or, until some pressure is



A. Toggle plate
B. Toggle plate pivot
C. Toggle plate stops
D. Toggle spring
E. High-pressure cutoff adjusting screw
F. Steel finger
G. Contact points
H. Contact points
J. Contact point adjusting screw
K. Low-pressure adjusting screw

Figure 37. Operation of pressure switch toggle plate (contact points closed).

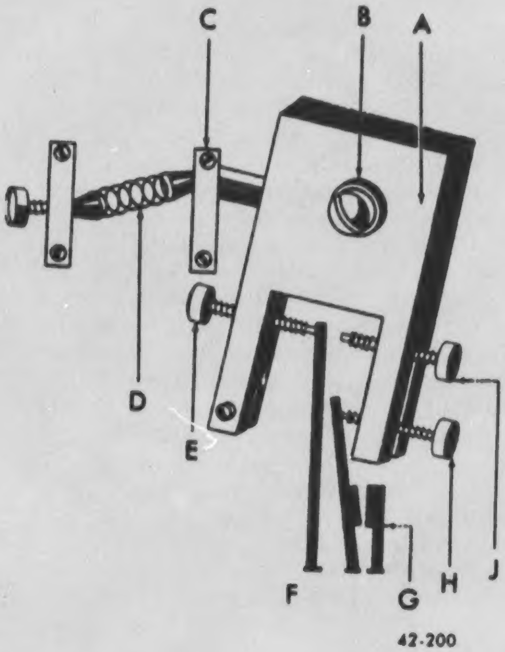
lost through normal internal leakage of the hydraulic units. When the pressure drops, the tube begins to recoil. At a certain point the finger pushes on the opposite inner surface (D) of the toggle plate. The toggle plate will then pivot quickly, letting the contact points close (complete) the circuit to the motor. Again, the pump will send fluid into the system to build up the pressure.

12-4. The operation of the toggle plate can be seen in figures 37 and 38. In order to show the operation of this toggle more clearly, the steel finger (F) is repositioned. It normally extends downward from the tip of the tube. In figures 37 and 38 it is shown extending in toward the center of the toggle plate (A).

12-5. Figure 37 shows the toggle plate position when the pump is operating, the system pressure is up, and the Bourdon tube is straightening out. The steel finger (F) pushes against the high-pressure, cutoff adjusting screw (E) and snaps the toggle plate (A) to the left on its pivot (B). As the toggle pivots left, the contact point adjusting screw (H) strikes the movable contact point of the contact points (G). Moving this point opens the circuit to the pump motor, as shown in figure 38.

12-6. Looking at figure 38, you will notice that the contact points are open. As the system pressure decreases, the tube begins to coil, and the steel finger (F) moves toward the right. It will then push against the low-pressure adjustment screw (J) and snap the toggle plate to the right. This allows the contact points (G) to close, completing the circuit to the motor; the pump will again send fluid into the hydraulic system.

12-7. It can be seen that the toggle spring (D) will not allow the toggle plate to remain in a neutral position. Thus, as the toggle plate snaps from one position to the other, the contact points are opened or closed rapidly. This insures less "burning" of the points. The toggle plate stop (C) limits the movement of the toggle plate (A).



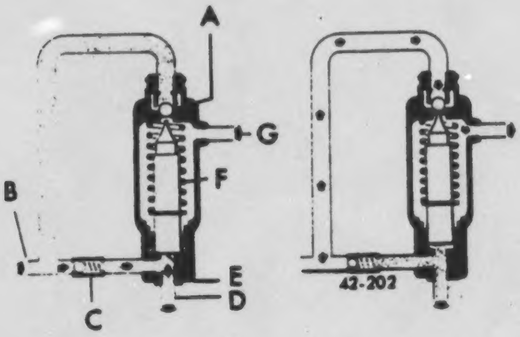
A. Toggle plate
B. Toggle plate pivot
C. Toggle plate stops
D. Toggle spring
E. High-pressure cutoff adjusting screw
F. Steel finger
G. Contact points
H. Contact point adjusting screw
J. Low-pressure adjusting screw

Figure 38. Operation of pressure switch toggle plate (contact points open).

12-8. You may sometimes be required to test and adjust a pressure switch like the one we just described. Since such occasions are not frequent we will not cover the procedure in this course. You can find the instructions in TOs. (Many new types do not require adjustment.)

12-9. **Pressure Regulators.** In the preceding chapter we discussed various types of power pumps that maintain a constant pressure output. These types do not need pressure regulators. Although manufacturers are using more variable-volume-type pumps, do not forget that pressure regulators do exist. Some of our present-day aircraft still use positive displacement pumps. These aircraft need regulators to maintain system pressure within the desired operating range. These pumps run continuously. Therefore, the regulator must be designed so that fluid can return to the reservoir when the system is fully pressurized. A bypass valve in the regulator does this job. A pressure regulator must also contain a check valve that will trap the fluid under pressure in the system. This valve allows fluid flow into the system, but prevents system fluid from flowing out through the bypass. A large spring is also included in the regulator for the system pressure to act upon. The spring is adjustable so that its compression can be varied.

12-10. Before we continue with this subject, we want to review the meanings of two terms. You must know them if you are to understand the operation of a pressure regulator. They are, "kicked in" and "kicked out." When the aircraft has not been in use for some time, its hydraulic system must be pressurized. The power pump begins to deliver fluid just as soon as the aircraft engine starts. We know that the hydraulic fluid must pass through the regulator before it can enter the system. For fluid to flow to the system, the regulator bypass must be closed, and the check valve must be open. Under these conditions, we say the regulator is "kicked in", and the pump is "loaded."



A. Bypass valve
B. Pressure input
C. Check valve
D. System connection
E. Piston
F. Spring
G. Line to reservoir

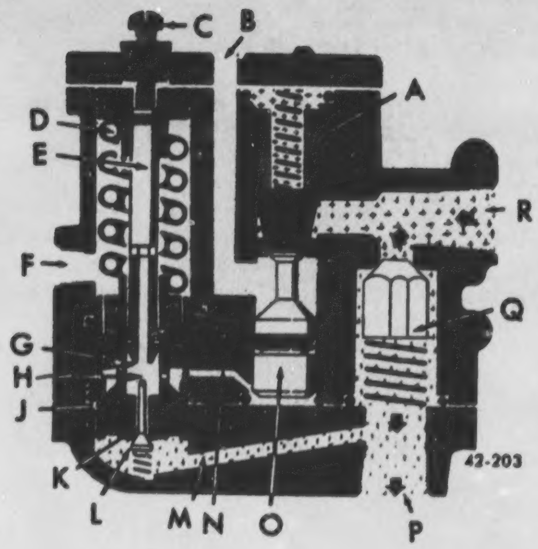
Figure 39. Pressure regulator.

12-11. The left illustration of figure 39 shows the pressure regulator "kicked in." While a unit is operating and full pressure is required, fluid will enter at line (B) and exit to the unit through line (D). When unit operating stops, the pressure builds up until the maximum desired pressure is reached. At that time the piston (E) will be forced up enough to move the bypass valve (A) off of its seat. Now the bypass opens a return path for pump output fluid. Since fluid takes the path of least resistance, it follows the return path back to the reservoir through the line (G). This is shown in the right-hand illustration of figure 39. The pump continues to operate, although it does not have to push the fluid out against pressure. Therefore, it is not constantly under a load, and we can expect trouble-free operation for a longer time. There is very little back pressure in the bypass route. Therefore, we have low pressure before the check valve, and high system pressure behind the valve. Naturally, the check valve closes and the system remains pressurized. This condition of the regulator is known as "kicked out." This kicked out condition lasts until the system pressure is used up or lost through internal leakage.

12-12. When system pressure drops to a certain point the spring (F) forces the piston (E) down, allowing the bypass (A) to close. When the bypass is closed, the pump's fluid output can no longer go directly to the return. Again, pressure will build up between the pump and the regulator. This pressure will open the check valve (C), and fluid will reenter the hydraulic system. It will build up the pressure to the desired maximum.

12-13. What have you learned? When the system pressure drops to a certain point, the pressure regulator will kick in and send fluid into the system. When the pressure has risen enough, the regulator will kick out, and bypass the pump's output back to the reservoir. Our pressure regulator has taken the load off the engine-driven pump and determined system pressure.

12-14. The difference between the regulator kick in pressure and the regulator kick out pressure is known as the operating range. After the aircraft engine has been started, our system pressure should be within this operating range. The operating range cannot be changed since this is built into the regulator. However, all regulators have a high pressure adjustment. If



A. Bypass poppet.
B. Return port
C. Adjusting screw
D. Compression spring
E. Hollow adjusting rod
F. Drain port to return
G. Upper (large) retainer
H. Needle poppet upper seat
J. Lower (small) retainer
K. Needle poppet lower seat
L. Needle poppet
M. Pressure-sensing line
N. Passageway to directional piston
O. Directional piston
P. System pressure port
Q. Check valve
R. Port from power pump

Figure 40. Selective-type double-area pressure regulator (kicked in).

the kick out pressure is increased or decreased, the kick in pressure will follow up or down. The kick out and kick in pressures can be changed, but the in-between range remains constant.

12-15. Selective-Type Pressure Regulators. We have two types of pressure regulators. They are called the *balanced-type* pressure regulator and the *selective-type* pressure regulator. Because the balanced-type is becoming obsolete, we discuss only the second type. Sometimes the second type is described as a selective-type double-area pressure regulator because the control section pressure works on two areas at different times. Examine figures 40 and 41. Controlling pressure works on the bottom of retainer J when the regulator is kicked in. It works on the bottom of retainer G when the regulator is kicked out. You will understand this better later on.

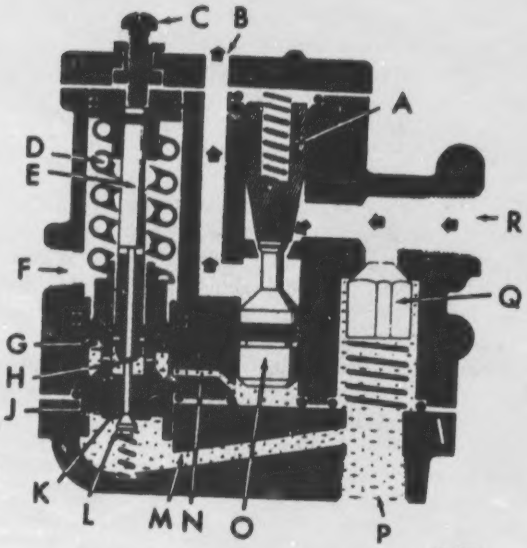
12-16. Refer to figure 40; notice that the fluid, under pressure, comes in port R from the power pump. Bypass poppet A is held closed by a spring. Therefore, the fluid can't bypass through return port B. It must open check valve Q and pressurize the system through system pressure port P. As system pressure builds up, it will pass through the pressure-sensing line (M). It will push up on lower (small) retainer (J). The lower retainer has a sleeve on its upper end that fits against a shoulder on the upper (large) retainer (G). Thus, as the pressure pushes the lower retainer up, it, in turn, raises the upper retainer compressing spring (D). As the lower retainer rises, needle poppet L rises with it. During this time, the needle poppet forms a pressure seal on the needle poppet lower seat (K).

12-17. At this point, look at the hollow adjusting rod (E). The lower portion is cut away to show its cross section and the hole drilled through it sideways. These cross holes vent the space between the retainers, passageway N, and the space under the directional piston (O). These spaces are vented to the drain port to return (F).

12-18. Now, back to the rising retainers. As they move upwards, the tip of the needle poppet (L) will seat in the lower opening of the hollow adjusting rod (E). Thus, a pressure seal is formed at the needle poppet upper seat (H). The needle poppet can rise no farther but the retainers keep moving up. This breaks the pressure seal at the needle poppet lower seat (K). At once, system pressure enters between the retainers, goes through passageway N and pushes up on piston O. Piston O unseats bypass poppet A. At once, system pressure coming in port R passes to the return line through port B. Now the power pump is "unloaded" and all its flow passes through this bypass route to the reservoir. At this time, there is little pressure above check valve Q and full system pressure below it. The system pressure and spring force slam the check valve shut. Thus, full operating pressure is kept in the system while the pump runs unloaded. The regulator is then kicked out (fig. 41).

12-19. In figure 41, we see the regulator kicked out. It will stay kicked out until system pressure drops. Either operating an actuator or internal leakage will drop it. Let's figure out how much it must drop before the regulator kicks in again. System pressure pushing up on the lower retainer is almost cancelled out by pressure pushing it down. But, system pressure is now also pushing up on the upper retainer

(G). The exposed lower area of the upper retainer is greater than was the exposed area of the lower retainer. Pressure acting on the lower retainer kicked the regulator out. Now, the pressure forces the upper retainer up farther and compresses spring D more. Remember the formula: total force = pressure × area. An amount of internal leakage or flow with pressure loss can occur in the system. This quantity will determine how long it takes the spring to force the upper retainer back down. When the retainer passes the point, on its way down, where kick out took place, kick in will occur. Figure 41 shows almost this exact moment. When the needle poppet unseats at H and seats at K, the pressure under piston O will dump into drain port to return F. Piston O will drop, bypass poppet A will close, and check valve Q will be forced open. The regulator is then kicked in (fig. 40), and the pump is loaded.



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A. Bypass poppet
B. Return port
C. Adjusting screw
D. Compression spring
E. Hollow adjusting rod
F. Drain port to return
G. Upper (large) retainer
H. Needle poppet upper seat
J. Lower (small) retainer
K. Needle poppet lower seat
L. Needle poppet
M. Pressure-sensing line
N. Passageway to directional piston
O. Directional piston
P. System pressure port
Q. Check valve
R. Port from power pump

Figure 41. Selective-type double-area pressure regulator (kicked out).

12-20. The distance the upper retainer moves up after the regulator kicks out is very important. It determines the pressure range between the kick out and the kick in pressure settings of the regulator. This can also be stated another way. It determines the length of time the pump can run unloaded when there is no hydraulic action required. This feature allows the pump to remain unloaded for a longer time. It also prevents the regulator from kicking in and out continuously.

12-21. **Maintenance of Pressure Regulators.** The pressure regulator is a reliable piece of equipment and causes little trouble to the hydraulic system. However, one hydraulic trouble that can be attributed to the regulator is an abnormal system operating pressure. This trouble can generally be corrected by adjusting the regulator while installed on the aircraft. Let's see how this adjustment is made.

12-22. If we wish to increase the kick-out pressure, we turn the adjusting screw (C in figures 40 and 41) counterclockwise. This allows the rod to rise. We found that the regulator does not kick out until the needle poppet (L) is unseated by the hollow rod. Therefore, the pressure must be higher before it can force the retainers and needle poppet up the added distance.

12-23. In all types and models of pressure regulators, the bypass allows fluid an unrestricted path to return; the check valve traps fluid in the system. The indication given by leaking check valves or bypasses, then, is the same for any regulator in any system. A leaking check valve seat causes an early kick-in, and a leaking bypass seat causes a late kick-out.

13. Accumulators

13-1. In Chapter 1, we explained the purposes of the accumulator. Summarizing, an accumulator is used:

a. To aid or supplement the power pump when several hydraulic units are operating at once.
b. For limited operation of a hydraulic unit when the power pump is not operating.
c. To dampen pressure surges in the hydraulic system.
d. To prevent rapid pressure losses which result from small leaks which would cause pressure switches to continuously kick in.

13-2. Accumulators are divided into types according to the way the air and fluid chambers are separated. In your work, you will see the diaphragm, bladder, and piston types. Of

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course, you will also see the combination reservoir-accumulator types. We discussed these in the section on reservoirs.

13-3. **Diaphragm-Type Accumulators.** Diaphragm-type accumulators consist of two hollow half-ball metal sections fastened together at the center line. See figure 42. One of these halves has a fitting for attaching the unit to the system; the other half is equipped with an air valve for charging the unit with compressed air. Mounted between the two halves is a synthetic rubber diaphragm that divides the tank into two compartments. A screen covers the outlet on the fluid side of the accumulator. This prevents a part of the diaphragm from being pushed up into the system pressure port and being damaged. This could happen when there is an air charge in the unit but no balancing fluid pressure. In some units a metal disc attached to the center of the diaphragm is used in place of the screen. The accumulator is usually mounted in the aircraft with the air chamber at the bottom.

13-4. The accumulator is charged with air when there is no fluid pressure in the system. This way, you can get an accurate measurement of the air charge. This air charge is usually higher than the fluid pressure required to operate any system unit. It forces the diaphragm upward against the inner surface of the upper section of the accumulator. When the fluid pressure increases above the initial air charge, fluid is forced into the upper chamber. This pushes the diaphragm down and further compresses the air in the bottom chamber. Hence, whenever there is any fluid forced into the accumulator, *the fluid and air pressures become the same.* Therefore, when the pressure regulator has kicked out and the power pump is idling, the system is still under pressure. This is because the accumulator air charge continues to push on the fluid in the system. The system stays pressurized and ready for use.

13-5. The accumulator is charged with air to a pressure greater than what is required to operate any unit. Should the power pump fail, any mechanism can be operated once and possibly more. The work output depends upon the volume of fluid stored in the accumulator. On some aircraft, the hydraulic pressure indication is taken from the air side of the accumulator. This is an advantage; the pilot or mechanic can read two pressures on the same gage. When there is no hydraulic pressure, the gage shows the mechanic the air preload pressure. When there is hydraulic pressure, the gage shows the pilot or the mechanic system hydraulic pressure.

13-6. **Bladder-Type Accumulators.** The bladder-type accumulator operates on the same principle as the diaphragm type. It serves the same purpose, but varies in construction (see fig. 43). This unit consists of a one-piece metal sphere with a fluid pressure inlet at the top. There is an opening at the bottom for inserting the bladder. A large screw-type plug at the bottom of the accumulator retains the bladder and also seals the unit. The high-pressure air valve is also mounted in the retainer plug. A round metal disc attached to the top of oh the bladder prevents damage caused by sudden discharge of fluid pressure. The disc prevents air pressure from forcing the bladder out through the pressure port. As fluid pressure rises, it forces the bladder downward against the air charge, filling the upper chamber with fluid pressure. The broken lines in figure 43 show the approximate shape of the bladder when the accumulator is charged.

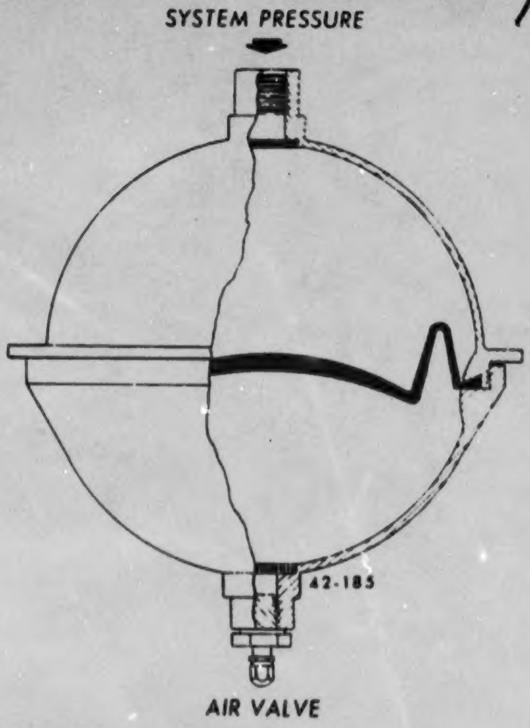


Figure 42. Diaphragm-type accumulator.

13-7. **Piston-Type Accumulators.** The piston-type accumulator also serves the same purpose and operates much like the diaphragm and bladder accumulators. As shown in figure 44, this unit is a cylinder (B) and piston assembly (E) with openings on each end. System fluid pressure enters the top port (A), and forces the piston down against the air charge in the bottom chamber (D). A high-pressure air valve (C) is located at the bottom of the cylinder for servicing the unit. There are two rubber seals

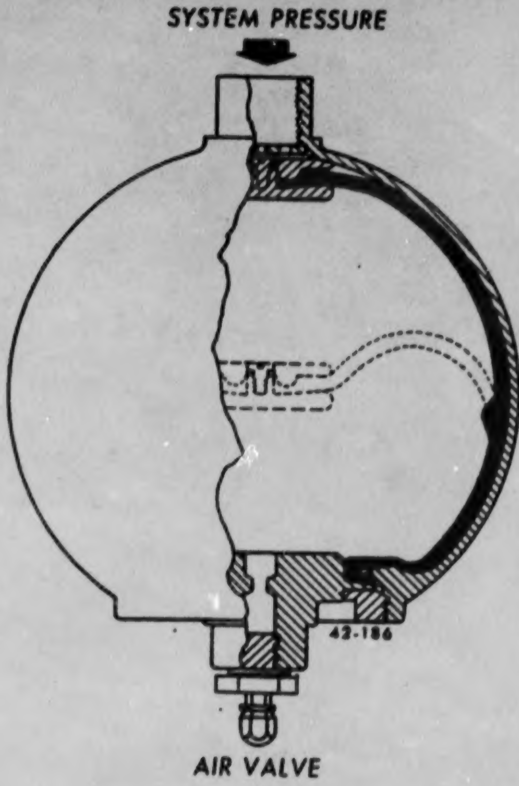
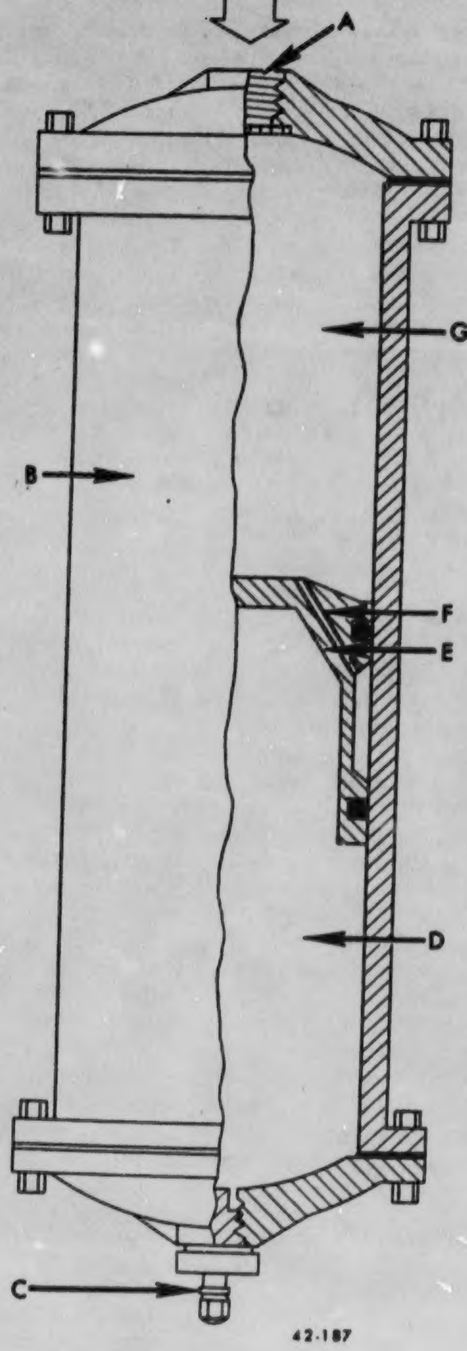


Figure 43. Bladder-type accumulator.

(represented by the black dots) which prevent leakage between the two chambers (D and G). A passage (F) is drilled from the fluid side of the piston to the space between the seals. This provides lubrication between the cylinder walls and the piston.

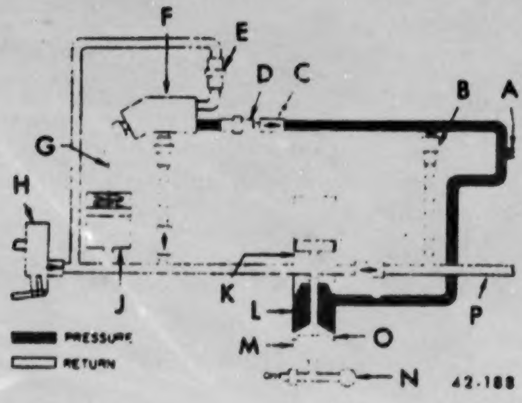
13-8. **Self-Displacing-Type Accumulators.** A fairly recent version of the accumulator is the self-displacing. It was developed for combat aircraft, where maneuverability at high speeds is desirable. Figure 45 shows a complete hydraulic power section having a self-displacing accumulator. A systemwith this kind of accumulator is completely free of any air; every portion of the system is completely filled with fluid. The self-displacing accumulator acts as a regular accumulator to store a volume of fluid under pressure. It also has a fluid storage chamber (K) that acts as a system reservoir under normal conditions. A system such as this is sometimes referred to as a "solid fluid system." This term is also used with the combination reservoir-accumulator covered in Section 8 on reservoirs.

13-9. The operation of the self-displacing accumulator is quite simple. With no hydraulic pressure in the system, the air charge in air



A. Fluid port
B. Cylinder
C. High-pressure air valve
D. Air chamber
E. Piston assembly
F. Drilled passage
G. Fluid chamber

Figure 44. Piston-type accumulator.



A. Line to actuating subsystem
B. Relief valve
C. Check valve
D. Line disconnect
E. Line disconnect
F. Pump
G. Sight gage, compensator assembly
H. Hand pump
J. Compensator reservoir
K. Storage space
L. Pressure chamber
M. Air chamber
N. Air pressure gage
O. Accumulator piston
P. Return line from actuating subsystem

Figure 45. Self-displacing accumulator system.

subsystem is actuated through line A, fluid is forced out of pressure chamber L. An equal amount of fluid will return through line P to fill the expanding storage chamber (K). When power pump F starts up again and forces fluid into pressure chamber L, it compresses the air in chamber M. As accumulator piston O moves downward, fluid is drawn from storage chamber K and pumped into pressure chamber L. This transfer of fluid is made by and through the power pump.

13-10. Since the amount of fluid exchange between chambers L and K is the same, the system always remains balanced. The air chamber is fitted with a high-pressure air valve to maintain the proper initial air charge. The top of the cylinder is vented in order to prevent back pressure caused by the piston when it moves up. Compensator J provides space for temperature expansion of the fluid. It also stores fluid to replace any lost through minor leakage. A mechanical sight gage (G) indicates the amount of fluid stored in the compensator.

13-11. Because of normal leakage in the system, periodic addition of hydraulic fluid is necessary. The hand pump (H) does this job. To replace fluid in the "solid fluid system," fluid is taken from the main system reservoir. Although not shown in figure 45, the hand pump also supplies fluid to other hydraulic systems on the aircraft.

13-12. There is an advantage to using this type accumulator. It allows the aircraft to fly in any attitude, vertical or inverted, and still maintain a constant hydraulic fluid pressure supply.

13-13. **Maintenance of Accumulators.** Maintenance consists of inspections, minor repairs, replacement of component parts, and testing. There is an element of danger in maintaining accumulators. Therefore, proper precautions must be strictly observed to prevent injury and damage.

13-14. Before disassembling any accumulator, make sure that all preload air (or nitrogen) pressure has been discharged. Failure to release the air could result in serious injury to the mechanic. (Before making this check, however, be certain you know the type of high-pressure *air valve* used.) When you know that all air pressure has been removed, go ahead and take the unit apart. Be sure, though, that you follow TO directives for the specific unit you have.

13-15. *Bladder- and diaphragm-type accumulators.* After disassembling, clean all metal parts with an approved solvent and then dry them thoroughly. The bladder or diaphragm usually should be replaced. Clean the new one with a lint-free cloth moistened with the type of hydraulic fluid used in the system. Inspect all metal parts for corrosion, cracks, and other evidence of damage. Inspect all threaded surfaces for stripped or worn threads. If they cannot be replaced, the bladder or diaphragm should be inspected for cracks, tears, and deterioration. Any part found to be defective should be replaced with a new one. Bladders and diaphragms stored for more than three years should not be used except in emergencies. In that case, they may be used only until new ones can be procured.

13-16. After a bladder- or diaphragm-type accumulator has been reassembled, it must be proof pressure tested and leak tested. To proof test the accumulator, you will need a test stand. It must put out controlled hydraulic pressure up to at least 5000 psi and air pressure up to at least 1000 psi. Before starting the test, be sure that everyone is shielded from the accumulator. Even though you assembled the accumulator correctly, there still is the possibility that it could blow up. Incidentally, remove the high-pressure air valve from the air chamber side of the accumulator for this test. To make the proof test, apply the specified fluid pressure (usually

3000 psi) to the fluid port of the accumulator. The accumulator must hold this pressure for a given time (generally five minutes). There must be no sign of leakage or failure. When it's determined that there are no leaks, release the pressure and drain the fluid.

13-17. In order to perform the leakage test, you must first reinstall the proper high-pressure air valve. Then charge the preload chamber with air to the specified pressure (generally 600 psi). With the air chamber charged, charge the fluid chamber to the value given in the applicable TO. This is usually in the neighborhood of 1500 psi. Then submerge the accumulator in hydraulic fluid and maintain the pressure for the specified time (usually 5 minutes). There must be no sign of air leakage during the test period. If the accumulator passes both the proof and leakage tests, it's ready for service.

13-18. *Piston-type accumulators.* When disassembling a piston-type accumulator, *never* force the piston out of the cylinder with air pressure. After disassembly, clean all parts thoroughly and inspect for damage. All minor nicks and scratches can be polished out with an approved type of crocus cloth. Replace all defective parts that are not repairable and all O-ring packings and gaskets. Lubricate all parts with clean hydraulic fluid (type used in the system) before reassembling.

13-19. After a piston-type accumulator has been reassembled, it must be friction tested, proof pressure tested, and leak tested. The friction test is made by determining that the pressure required to move the piston is within limits. Position the piston close to an end-cap and connect this end-cap to a source of fluid pressure. Then slowly apply increasing fluid pressure until the piston moves the length of the cylinder. Next, connect the opposite end-cap to the fluid pressure source and repeat the test. Repeat this complete cycle. This insures that the piston moves through its complete travel at or below the fluid pressure specified in the TO. If it passed the friction test, move the piston to midpoint to ready the accumulator for the proof pressure test.

13-20. Now to perform the proof pressure test. Fill the air chamber with test fluid (generally hydraulic fluid) and close the port with a pressure gage. If the proof pressure is 6000 psi, for example, the gage should go up to 10,000 psi. Fill the fluid chamber with fluid and attach this chamber to a proof pressure source. Slowly pressurize the accumulator to the required proof pressure and maintain for the specified time limit. Any external leakage is cause for rejection. After this test, drain both ends thoroughly to ready the accumulator for the air leakage test.

13-21. Perform the air leakage test as follows. Connect a source of dry filtered air or nitrogen pressure to the air chamber end-cap. Slowly apply pressure until the piston bottoms lightly against the open hydraulic end-cap. Next, stand the accumulator vertically with the hydraulic port up. Then fill the hydraulic end with the specified test fluid and leave the port open. Continue to hold the accumulator in a vertical position. Raise the air pressure about one-tenth of the normal preload value and hold for a specified period of time. Any air bubbles coming up through the fluid indicate leakage. Now raise the preload pressure to its normal value and hold for a specified time limit. Any leakage at either pressure is cause for rejection.

13-22. The air leakage test can also be performed by pressurizing the accumulator to its normal preload air pressure. Then submerge it in a tank of hydraulic fluid and watch for bubbles.

13-23. When the tests are finished, depressurize and drain the accumulator of excess fluid. Next, cap all ports.

14. Relief, Purge, and Pressure Reducing Valves

14-1. Each of these valves effects the pressure in the hydraulic system. They may not seem as important as some other units but they increase efficiency and safety. So now, let's see what they do.

14-2. **Relief Valves.** Relief valves are simply pressure-limiting devices. They prevent pressure from building up to where it might burst its container. How could this happen when we have a pressure regulator or pump compensator to control pressure? It couldn't normally; but, if one of these units should fail, the relief valve is there as a backup safety device. It will limit the maximum pressure reached in the system by dumping the pressure. Thus, the main system relief valve must be large enough to pass the pump's full output back to the return. This does not, however, unload the engine-driven pump as a pressure regulator does; the pump must still maintain enough pressure to keep the relief valve open.

14-3. We also may have smaller relief valves in isolated parts of the system. These valves are of the same construction as the main system relief valves, but are small in size. They are used in closed parts of the system. These are where check valves or selector valves prevent pressure from being relieved through the system relief valve.

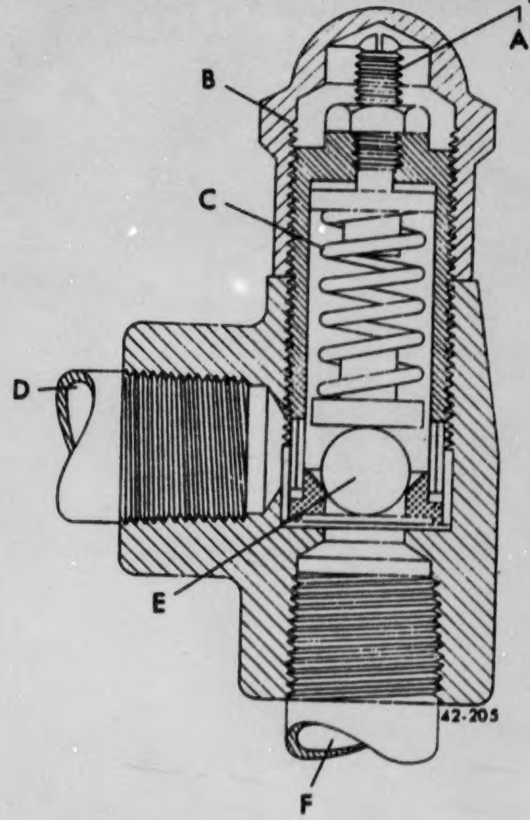
14-4. These small relief valves are also used to relieve the pressure caused by thermal expansion of the fluids. Since the volume of fluid to be relieved is small, the valve can be small and still do its job. These relief valves are called thermal expansion relief valves, commonly labeled "TERVs."

14-5. Relief valves have an adjustment for increasing or decreasing the pressure at which they relieve. The adjusting screw is usually covered by a cap. To increase the pressure at which the valve relieves, turn the adjusting screw clockwise.

14-6. In figure 46 we see a typical two-port relief valve. The pressure from the system enters the pressure port (F) and pushes upward on the ball (E). If this pressure is high enough to overcome the compression spring (C), the ball will be pushed off its seat. Now fluid from the system can go out the return port (D) to the return line. The adjusting screw (A) merely increases or decreases the force of the spring. As a result, it requires more or less pressure to unseat the ball. The cap (B) protects the adjustment screw.

14-7. In this relief valve we have seen that the system's pressure acts against a large spring. The spring doesn't need to be as strong as you may think, because the pressure acts on only a small area. Let's say we want the valve to relieve at 2000 psi. If the ball seal area of the relief valve is 1/4 square inch, the spring force need be only 500 pounds. The formula $F = A \times P$ can be used to find the spring force. For example, Force = 1/4 sq in (area) × 2000 psi (pressure) = 500 lbs.

14-8. Figure 47 shows a slightly different relief valve, but it works on the same principle. The main difference is in the hookup. Since this valve has four ports, we can run the pressure line through the bottom ports. The return line to the reservoir can be run through the top ports. Another difference in this relief valve is that the ball (D) remains stationary. Pressure acting on the bottom area of the ball seat sleeve (C) pushes it up. This gives the pressurized fluid a path to the return line. One pressure port and one return port may be plugged on this valve so it can be used as a two-port type. The pressure adjustment nut (B) regulates the tension on the compression spring (A).



A. Pressure-adjusting screw
B. Adjusting screw cap
C. Compression spring
D. Return port
E. Ball
F. Pressure port

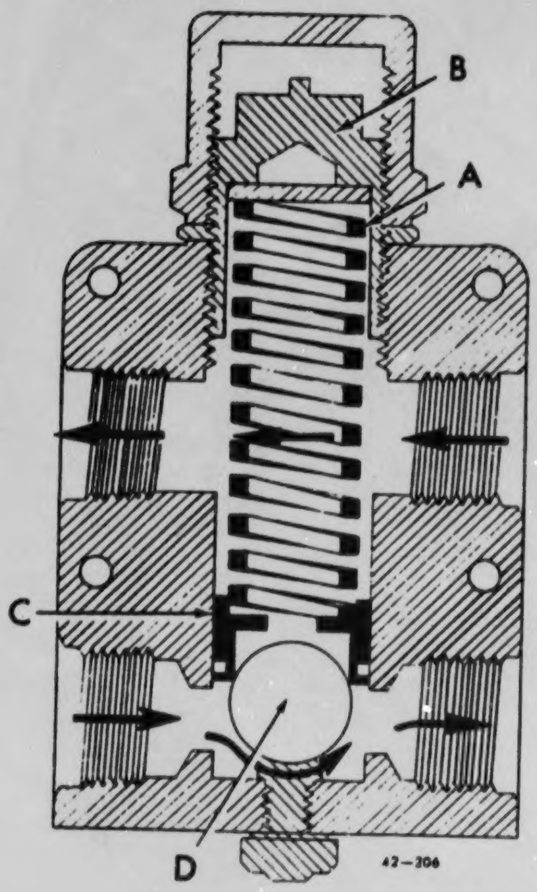
Figure 46. Two-port relief valve.

14-9. Thus far we have considered only the spring force that must be overcome before the valve relieves. In the hydraulic system, however, we also have some pressure in the return line. This pressure helps to hold the ball on its seat. Return line back pressure is caused by resistance in the return line and may be as high as 250 psi. The area on which this back pressure works effectively can be seen in figure 48. The back pressure acts all the way around the ball, except on that portion exposed to system pressure. Thus, the back pressure acting on one side of the ball is canceled by that acting on the other side. Therefore, system pressure (B) must overcome only the back pressure acting on the top (A) of the ball.

14-10. The pressure at which the valve will relieve increases directly with an increase in back pressure. In our previous example there was no back pressure. System pressure overcame the spring force and unseated the ball at 2000 psi. We will now put this valve in a system having 150 psi back pressure. There it will take 2000 psi + 150 psi or 2150 psi to unseat the ball. For this reason, relief valves should be adjusted while on the aircraft.

14-11. The pressure at which the ball is slightly unseated is called the *cracking pressure*. At this pressure, only a few drops of fluid are relieved. If more fluid needs to be relieved, the ball will rise higher and allow full pump output to be relieved. This is called the valve's *full flow pressure*. It is about 10 percent higher than cracking pressure because the spring must be compressed further. After the valve has relieved fluid and the pressure drops, the ball must stop fluid flow around it. Fluid tends to continue flowing once it has started. So, the spring cannot force the ball on its seat until pressure has dropped about 10 percent below cracking pressure. This pressure at which the return flow is cut off is called the *reseating pressure*. Most relief valves are adjusted to the cracking pressure.

14-12. Some special relief valves are constructed with a rod on top of the ball. (See fig. 49.) The diameter of the rod (E) is equal to the diameter of the system pressure port under the ball (D). It is so constructed that the back pressure cannot act downward on the ball surface covered by the rod. The back pressure acting on the sides of the ball is the same as in the subsystem line (B). In this type relief valve, called a balanced type, the back pressure has no effect on when the valve relieves. This valve does not eliminate back pressure, but it does remove its effect on valve operation. The line from the pressure manifold (C) provides system pressure. The vent (A) prevents air pressure build-up in the chamber above the rod (E) when it moves upward. The O-ring (F) provides a seal around the rod.



A. Compression spring
B. Pressure adjustment
C. Ball seat sleeve
D. Ball

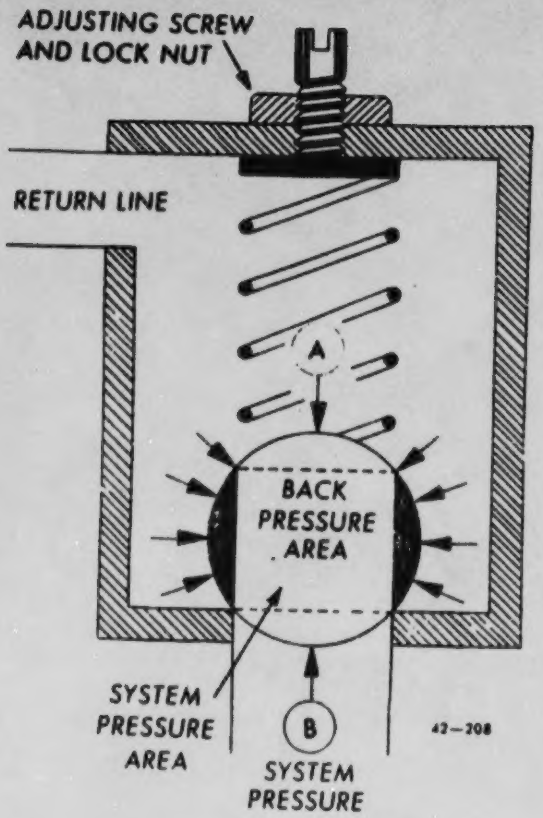
Figure 47. Four-port relief valve.

14-13. *Repair of relief valves.* Relief valves, like most other hydraulic units, normally require little maintenance. However, they do occasionally fail. The most common trouble you will find with relief valves is internal leakage.

14-14. The repair that your shop will perform on relief valves depends on the type of valve and the available facilities. Some types of relief valves are not repaired. Others may be disassembled, inspected, repaired, and reassembled. Repairs consist primarily of polishing and lapping the various internal components. Again, we repeat, repairs must be made according to TO directives. These procedures will definitely vary, depending on the design of the particular unit.

14-15. *Adjustment of relief valves.* Relief valves are usually preset on a test bench before installation. However, they must be checked periodically while installed on the aircraft. Therefore, we will give a general discussion on how to perform an adjustment. Keep in mind, however, that the adjustment procedure varies.

14-16. To make an adjustment, you have to pressurize the aircraft hydraulic system with a portable hydraulic test stand. So, start the test stand and adjust its compensator to regulate the pressure. It should be 25 to 50 psi above the aircraft relief valve setting. Then adjust the test stand relief valve to 100 psi above the compensator setting. This allows enough pressure to assure proper adjustment of the aircraft relief valve without danger of overloading the system. After these two adjustments are made, connect the test stand to the aircraft. Now apply test stand pressure to the system at a rate of 6 to 10 gallons per minute. Note from the cockpit indicator the existing kickout value of the aircraft relief valve. Then release the test stand pressure from the system. Remember, pressure should be released from the system before attempting any adjustment. This is to prevent possible damage to the threads of the adjusting screw.



A. Area upon which back pressure exerts a downward force

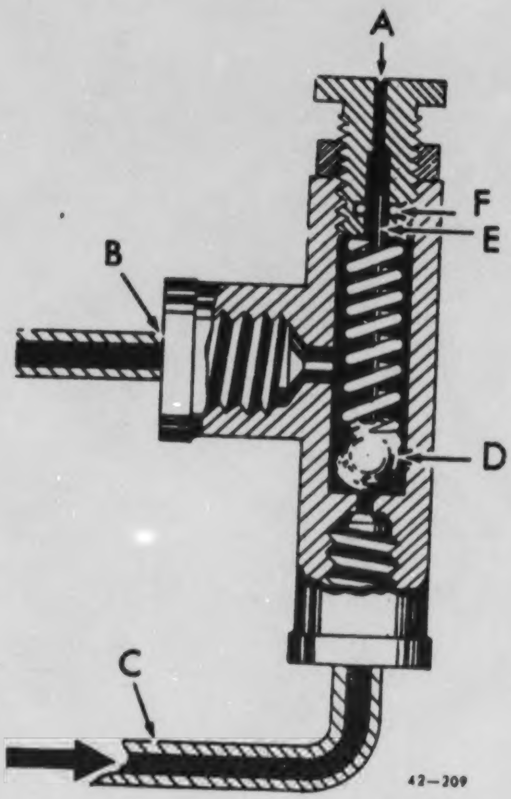
B. Area upon which system pressure acts

Figure 48. Relief valve (area upon which back pressure is effective).

14-17. When the test stand pressure is released from the system, start the adjustment. Loosen the aircraft relief valve adjusting screw locknut and turn the screw 1/8th turn clockwise to increase kickout pressure; turn it counterclockwise to decrease kickout pressure. The pressure change made by 1/8th turn will help determine the amount of turn needed next time. Now apply test stand pressure to the system as done previously. Note the cockpit indicator for the newly established relief valve kickout pressure. Again, release the test stand pressure and turn the adjusting screw to obtain the desired value. After the proper kickout pressure is obtained, tighten the locknut while holding the screw in its correct position.

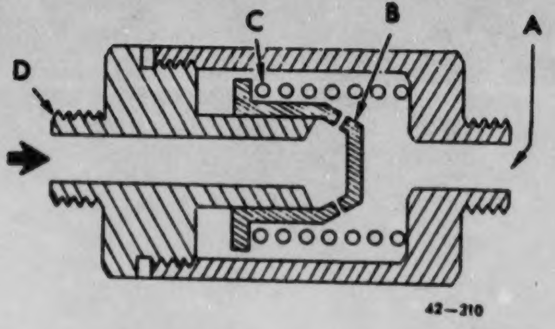
14-18. After you have tightened the adjusting screw, apply and release the test stand pressure several times. Check the cockpit pressure indicator each time to see that the relief valve kicks out at the desired pressure. Finally, shut down and disconnect the test stand from the aircraft.

14-19. **Purge Valves.** Purge valves are installed on many of our aircraft hydraulic systems to release air from the pressure lines. The purge valve (fig. 50) is essentially a relief valve with the spring installed in reverse. That is, the spring keeps the valve open instead of closed, as in the case of a regular relief valve. The valve is normally connected between the pump pressure line and the manifold return line. When the pump output drops below a certain pressure, the spring (C) will force the plunger (B) to the open position. Figure 50 shows the purge valve in the open position. Air in the pressure line can enter at the inlet (D), pass through the slits in the plunger (B) and out through the outlet (A). Figure 51 shows the purge valve installed in a system. When the purge valve opens, fluid flows from the pump (C) through the purge valve (E), back to the



A. Vent to atmosphere
B. Line to subsystem selector valve
C. From pressure manifold
D. Ball
E. Rod
F. O-ring seals

Figure 49. Balanced relief valve.



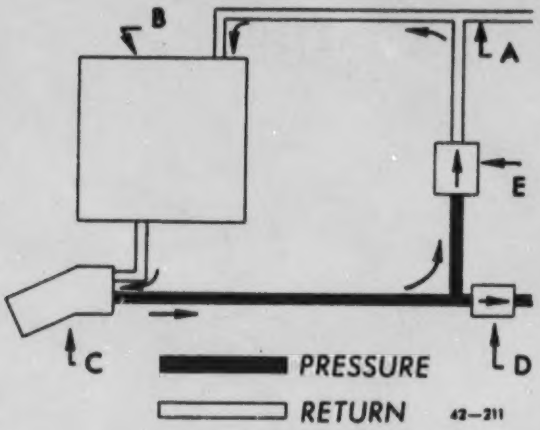
A. Outlet
B. Plunger
C. Spring
D. Inlet

Figure 50. Purge valve (open position).

return line (A). From there it flows to the reservoir (B) and again, to the pump.

14-20. During aircraft maneuvers, air is very likely to get into the pump supply and output lines. When this happens, the output pressure will drop. When the fluid pressure drops enough, the spring will open the purge valve. This allows the air to escape back to the return manifold and the reservoir where it is discharged. As the air is purged from the system, pure fluid will be pumped. Fluid pressure will again build up and overcome the spring force and close the valve. When the valve closes, the pump's output is directed into the pressure manifold.

14-21. The purge valve also serves another purpose. This is when it is used with electrically driven and turbine-driven emergency pumps. Let's say that in figure 51 the system beyond the check valve (D) is pressurized. Also that the pump is started. If it must start against such a load, it could easily stall and the driving unit be damaged. With the purge valve installed as shown, the first limited flow will be routed back to the reservoir. As soon as the pump comes up to speed, the pressure will build up enough to close the purge valve. Now the fluid will flow out to the pressure lines through the check valve.



A. Return manifold
B. Reservoir
C. Pump
D. Pressure manifold check valve
E. Purge valve

Figure 51. Typical installation of a purge valve.

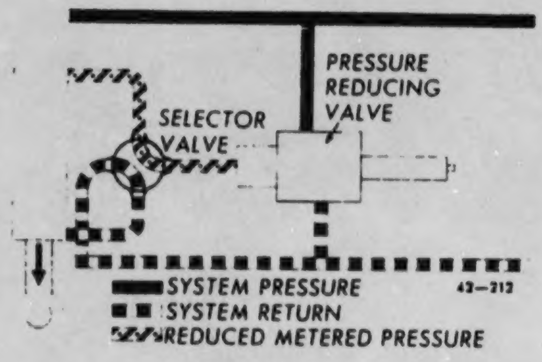
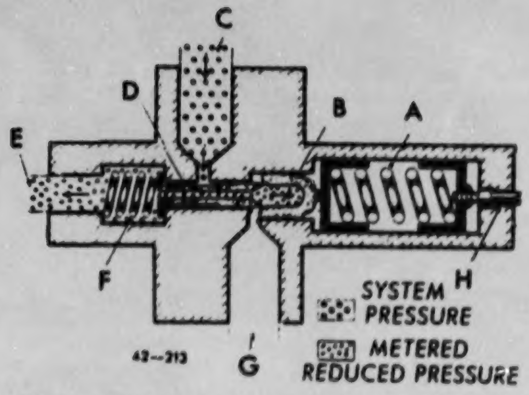


Figure 52. Typical installation of a pressure-reducing valve.

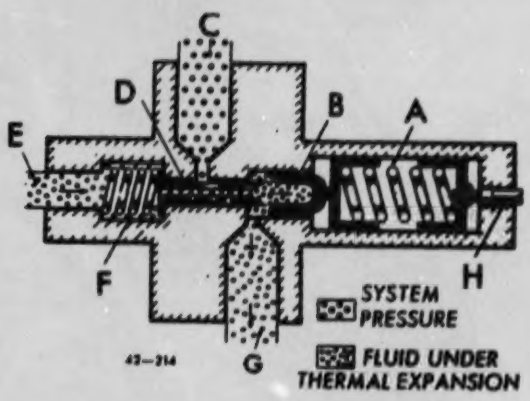
14-22. **Pressure-Reducing Valves.** We have learned that pressure regulators can maintain system pressure between two limits, and relief valves can limit maximum pressure. Yet, in certain situations these units may not meet our needs. In some section of the system, we may not want to use full system pressure. It may be that the actuator in a subsystem is not designed for the high pressure we have in the system. Or perhaps we want a reduced operating pressure to prevent overloading some structure. Whatever the reason, a *pressure-reducing* valve is what we need. This valve will reduce system pressure to the desired level; it will also relieve thermal expansion in the section of the system that it isolates. In figure 52 we see how a pressure-reducing valve is installed in a system. It brings about a lower pressure for operation of the actuating cylinder.

14-23. The pressure-reducing valve has three ports. One of these (C) is connected to system pressure, one (G) to the system return line, and the third (E) is the reduced-pressure port. Figure 53 shows the valve as it reduces pressure. The pressure-adjusting spring (A) holds the reservoir return valve (B) and the poppet (D) to the left. Fluid under system pressure enters the system pressure port (C). It passes around the unseated poppet and out the reduced-pressure port (E). Soon the pressure



A. Pressure-reducing spring
B. Reservoir return valve
C. System pressure port
D. Poppet
E. Reduced-pressure port
F. Poppet spring
G. Reservoir return port
H. Pressure-adjusting screw

Figure 53. Pressure-reducing valve.



A. Pressure-reducing spring
B. Reservoir return valve
C. System pressure port
D. Poppet
E. Reduced-pressure port
F. Poppet spring
G. Reservoir return port
H. Pressure-adjusting screw

Figure 54. Pressure-reducing valve relieving thermal expansion.

going out the reduced-pressure port (E) builds up. The pressure is transmitted back through the hollow poppet (D) and exerts a force on the reservoir return valve (B). When this force overcomes spring (A) force, the reservoir return valve is pushed to the right. Now the poppet spring (F) seats the poppet. This stops the system pressure which was going out the reduced-pressure port (E) from building up further pressure there. The inlet pressure (C) has no effect on the poppet itself. The reason is that the areas on the ends of the poppet exposed to the pressure are the same; therefore, the forces exerted on the poppet are balanced. The pressure exerts an unbalanced force only on the area of the reservoir return valve (B).

14-24. In actual operation this pressure-reducing valve will close when the desired pressure is reached and held. But in continuing operation of the actuator using the reduced pressure, the valve will vary its opening. It varies its opening to meter the fluid at the speed required to maintain the desired pressure.

14-25. Figure 54 is the same as figure 53 except that it shows a static condition. If the actuator is not in use, no fluid flows. The fluid between the reducing valve and the selector valve is trapped. If thermal expansion occurs in this line (port E), the increased pressure will push the reservoir return valve (B) to the right. This movement allows a small amount of fluid to be relieved out the return port (G). Then the spring will close the return valve (B), and the fluid will be trapped at the proper pressure again.

14-26. The pressure reducing valve has a pressure-adjusting screw (H) to change the reduced pressure. Turning the screw counterclockwise increases the adjusting spring (A) pressure. This increases the metered pressure.

14-27. Sequence Valves. Sequence valves are installed on many of our aircraft hydraulic systems to allow certain operations to take place in a given manner (sequence). These valves are pressure, mechanical or electrically operated. Their construction is similar to the relief valve.

14-28. Operation of sequence valves is found in Vol III, Chapter 4 of CDC 42152.

Flow Control and Directional Units

YOU HAVE SEEN how pressure is built up, regulated, stored, and limited. You must also know about the units that control the flow and direct it to the actuating units. These include selector valves, check valves, flow regulators, flow equalizers, variable restrictors, hydraulic fuses, quantity-measuring fuses, and several other units.

15. Selector Valves

15-1. Selector valves are used in hydraulic systems to control the directional movement of mechanisms. For this reason they are often called *directional control valves*, or *control valves*. The type of valved used depends upon the type of system, the type of actuator, and the manufacturer's desires. It also depends upon whether the valve is to be used in a closed- or open-center system. A schematic comparison of the operation of the two types of selector valves is shown in figure 55.

15-2. When an open-center selector valve is in neutral, fluid will flow right through it without hindrance. A number of open-center selector valves are always placed in series. That way, if they are all in neutral, the power pump runs unloaded. Not until any one selector valve is turned, will fluid flow to an actuator. Then the pressure builds up in the pressure line. These valves are used mainly on test stands today. Most aircraft selector valves are the closed-center type. They are placed in parallel between the pressure manifold and return manifold. They block fluid flow when in neutral. Therefore, variable volume power pumps or pressure regulators are used in a closed-center system.

15-3. The operation of either type selector valve in any position except neutral will be the same. Fluid from the pressure manifold is sent into either alternating line, depending upon the setting of the valve. The return manifold is always connected to the opposite line. Notice that when the closed-center selector valve is in the neutral position, it stops the flow of fluid. The pressure manifold is always pressurized. When the selector valve for the open-center system is in the neutral position, the pressure manifold is unpressurized. The fluid from the pressure manifold has free flow into the return manifold through the selector valve.

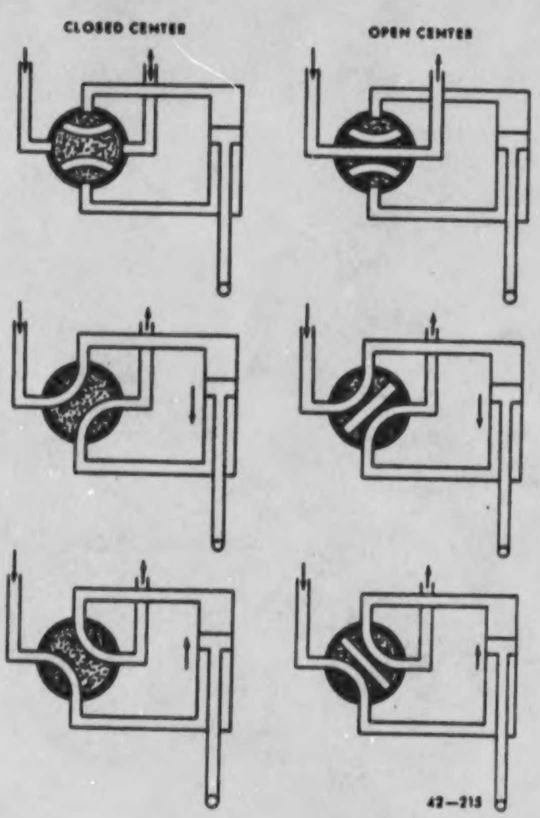
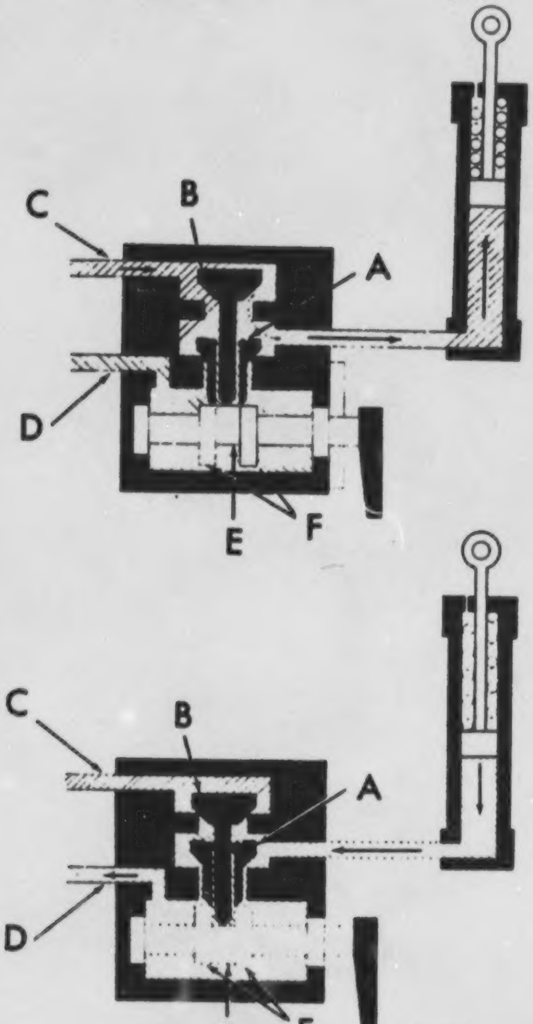


Figure 55. Open- and closed-center rotor-type selector valves.

15-4. **Three-Way Selector Valves.** A poppet-type three-way selector valve is shown in figure 56. This type of selector valve operates a unit hydraulically in one direction; it permits either the load on the unit or a spring to return the unit to its original position.

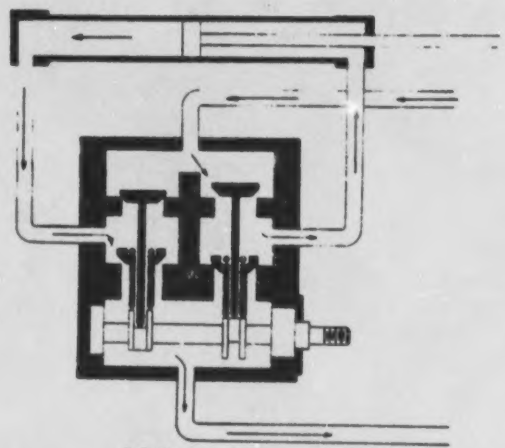
15-5. The top illustration of figure 56 shows hydraulic pressure forcing the piston outward against a load. The upper poppet (B) is unseated by the inside cam (E). This permits fluid to flow from the pressure line (C) into the cylinder to actuate the piston. The lower poppet (A) is seated, sealing the return manifold. In the bottom illustration the selector valve has been turned to the opposite setting. The upper poppet (B) is seated, sealing the fluid from the pressure line (C). The lower poppet (A) is unseated by the outside cam (F). The fluid forced from the cylinder can flow through the selector valve into the return line (D).



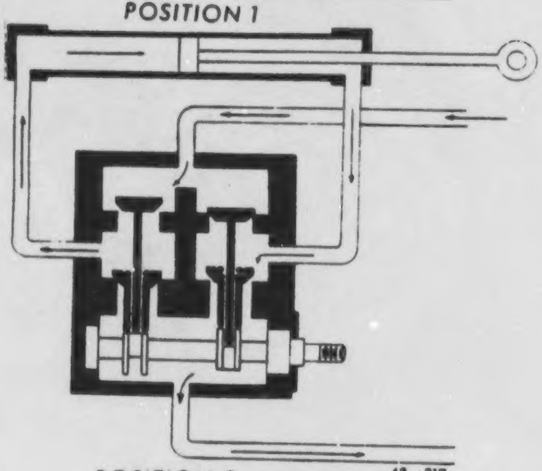
A. Lower (return) poppet
B. Upper (pressure) poppet
C. Pressure line
D. Return line
E. Inside cam
F. Outside cam

Figure 56. Three-way poppet-type selector valve.

15-6. **Four-Way Selector Valves.** An example of a four-way selector valve is shown in figure 57. Notice that this valve is also a poppet type. The cam and poppet arrangement of the four-way poppet-type selector valve is much like that in the three-way valve. The main difference is that two sets of poppets are used instead of one.



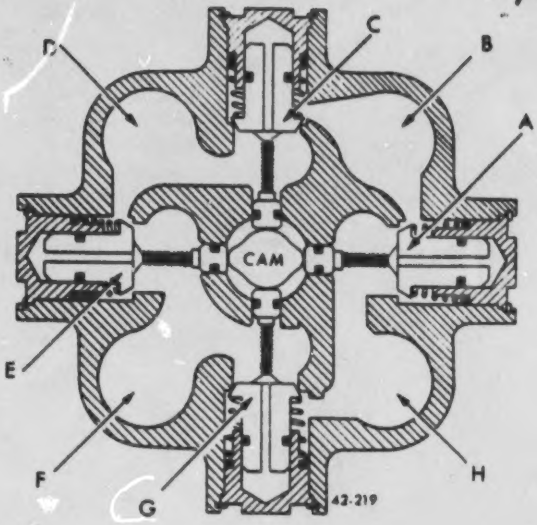
POSITION 1



POSITION 2

Figure 57. Four-way poppet-type selector valve.

15-7. In the neutral position (not shown) all four poppets are seated, or closed. This type selector valve relieves high pressure trapped in the actuating lines because of high temperatures. This excessive pressure will lift the upper poppet valves and relieve into the system pressure manifold. (All pressure lines feed off the pressure manifold. Return lines feed into the return manifold.) It may seem strange that pressure due to thermal expansion can be relieved into a pressure line. Pressures in excess of normal system pressure are dangerous. The system is built to withstand system pressure, but thermal pressures go much higher than system pressures. Consequently, thermal pressures are relieved into system pressure lines before a critical value is reached.



A.	Poppet	E.	Poppet
B.	Pressure port	F.	Return port
C.	Poppet	G.	Poppet
D.	Alternating line port	H.	Alternating line port

Figure 59. Four-port radial-type selector valve (schematic diagram).

15-8. Critical pressure would, in this case, be a pressure high enough to damage the system or its units. The system relief valve's function is to prevent the *system* pressure from ever reaching the critical value. In some instances a check valve is installed in the pressure manifold leading to the selector valve. This valve allows fluid to enter the selector valve from the pressure manifold, but does not allow reverse flow. When such a check valve is installed it does not permit relief of thermal expansion into the pressure manifold. In this case, a thermal expansion relief valve is inserted between the check valve and the selector valve. This relieves excessive pressure into the *return* line.

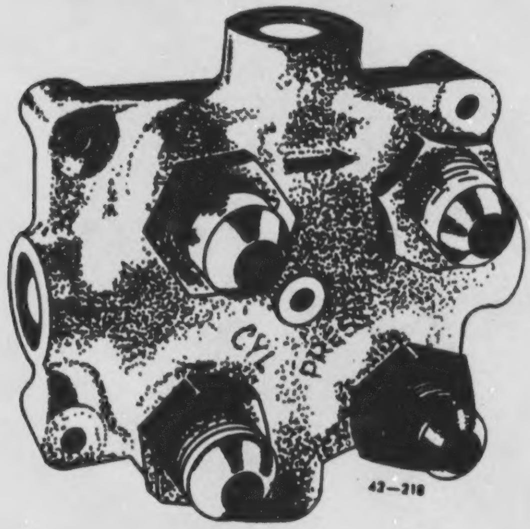


Figure 58. Four-port radial-type selector valve.

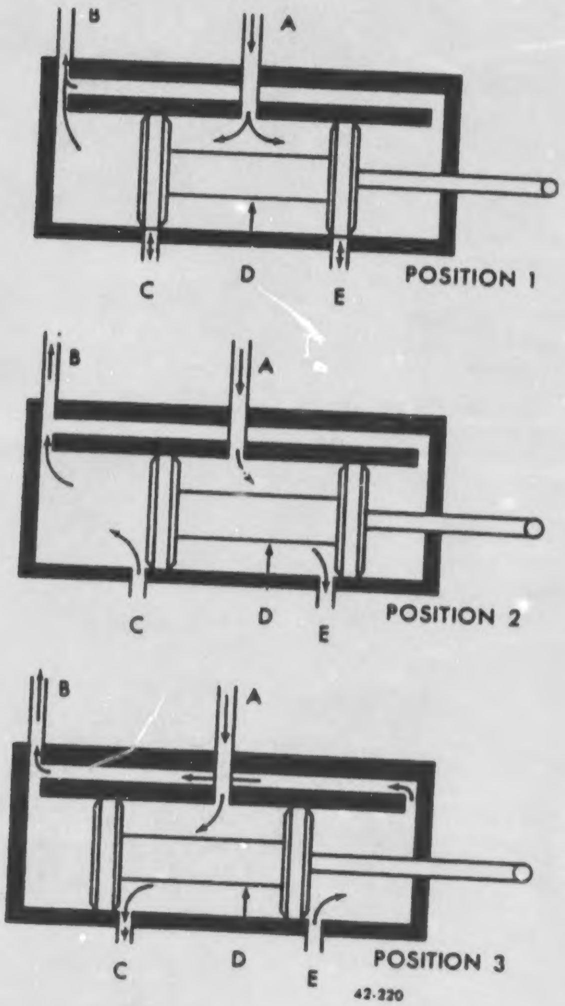
15-9. **Radial Selector Valves.** A picture of the radial selector valve is shown in figure 58. A schematic diagram is shown in figure 59.

15-10. Notice that all ports enter the selector valve on the same side in figure 58. Because of this, the schematic (fig. 59) does not show the external ports themselves. It shows where they enter to match figure 58. The port entrances are at B, D, F, and H of the schematic. The upper right port (B) is attached to the pressure manifold. The lower left port (F) is attached to the return manifold, and the other two ports (D and H) are attached to the opposite sides of the actuator. The cam in the center is attached to the control handle on the back side of the valve. Rotation of the cam causes the poppets (A, C, E, and G) to be moved on or off of their seats. The schematic diagram shows the cam is holding poppets A and E off their seats. In this position fluid under pressure enters upper right port (B), flows around right-hand poppet (A). It flows out to the actuator through the lower right port (H). At the same time, fluid returning from the actuator enters upper left port (D). It flows around left-hand poppet (E), and exits through lower left port (F) to the return manifold.

15-11. If the cam is rotated 90°, the left- and right-hand poppets (A and E) seat and the other poppets (C and G) will unseat. This allows the pressurized fluid entering upper right port (B) to pass through upper left port (D) to the actuator. Fluid returning from the actuator enters the selector valve at lower right port (H). It flows by poppet (G) and leaves through lower left port (F). If the cam is rotated only 45°, the lobes of the cam do not push the poppets off their seats, and the selector valve remains in neutral.

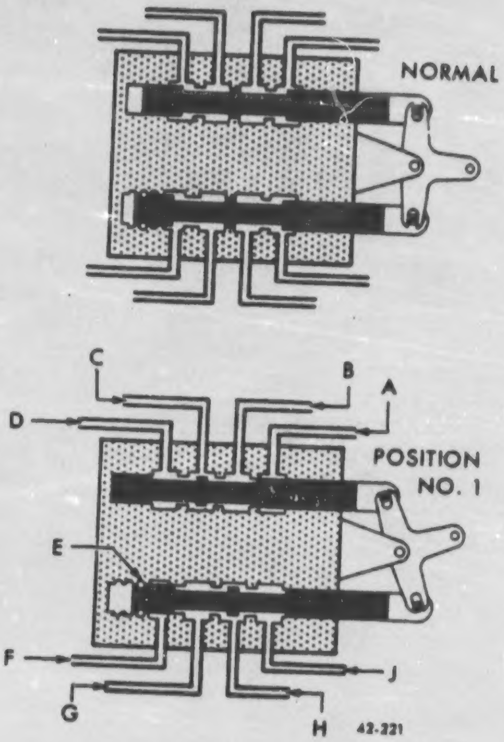
15-12. You may sometimes be required to adjust and bench test the poppet-type radial selector valve. In figure 59, notice the screws that link the cam riders to the poppets. Adjusting the length of the piston screws controls the amount of poppet travel. If the screws are shortened too much, it will prevent the poppets from opening soon enough or far enough. This causes a delay in the start of operation and a decrease in the volume of fluid flow. This, in turn, results in slower operation of the actuated component. Lengthening the screws too far allows the poppets to open too soon and too far. This results in faster operation of the actuated component. The higher speed could cause damage to equipment and injury to personnel. Thus, you can see that it is very important that the poppets be properly adjusted. For the adjusting and testing procedures, always follow the instructions given in the applicable TO.

15-13. **Compound Selector Valves.** When banks of units are to be controlled, several selector valves are compounded into one unit. This conserves space and simplifies installation. Each selector valve is controlled independently by a separate control handle. The primary difference is that only one connection is needed for the pressure manifold and only one for the return manifold. It is not necessary to have pressure and return connections for each selector valve.



A. Pressure port
B. Return port
C. Alternating line port
D. Piston spool
E. Alternating line port

Figure 60. Slide-type selector valve.

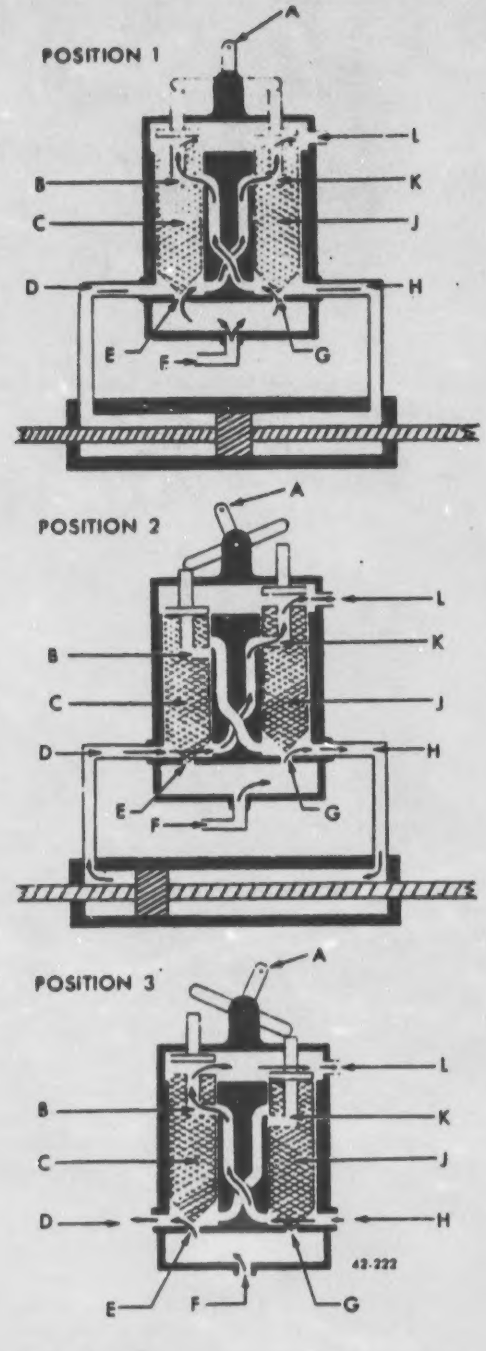


A. Pressure line from No. 2 power supply system
B. Pressure line to No. 2 system actuating units
C. Pressure line to No. 1 system actuating units
D. Pressure line from No. 1 power supply system
E. Snapspring
F. Return line to No. 2 power supply system
G. Return line from No. 2 system actuating units
H. Return line from No. 1 system actuating units
J. Return line to No. 1 power supply system

Figure 61. Slide- or piston-type selector valve.

15-14. **Slide- or Piston-Type Selector Valves.** The slide- or piston-type selector valve requires only a short movement of the linkage to the selector valve to actuate it. It is used in closed-center boost systems, nose wheel steering systems, wing flap systems, and other sub-systems having variable position control. One of the major advantages of this type of valve is its metering ability. It does not have to be positioned all the way open unless desired. For this reason, a mechanism can be operated at varying speeds. The rate of fluid flow going through the valve can be controlled. Frequently this valve is referred to as a "metering valve."

15-15. Figure 60, position 1, shows the metering valve in the neutral position. Fluid under pressure fills the space between the ends of the piston spool (D). Because the alternating ports (C and E) are closed, the fluid is trapped. Position 2 shows piston D moved to the right. This allows pressure from pressure port A to



A. Positioning arm
B. Passage
C. Plunger
D. Alternating port
E. Variable opening (plunger seat)
F. Pressure inlet port
G. Variable opening (plunger seat)
H. Alternating port
J. Plunger
K. Passage
L. Port to return line

Figure 62. Variable-restrictor control valve.

enter the right-hand alternating line (E). The other alternating port (C) is connected to the return manifold through return port B. Position 3 shows piston D moved to the left. This allows pressure to enter the left hand alternating line (C). The other alternating line (E) now connects to return B through the drilled passageway across the top.

15-16. Another design of the slide- or piston-type selector valve is shown in figure 61. This type of valve is generally used on larger type aircraft. With this valve, either one of the two hydraulic power systems can route fluid to the units of any actuating subsystem. Normally, each power system serves certain actuating subsystems. In emergency, this "crossover" selector valve lets each power system serve the other power system's actuating units.

15-17. The pressure of one system may become too low for proper operation of its hydraulic units. This would often be considered an emergency. This selector (or *crossover*) valve can be positioned so the other system provides pressure for both systems.

15-18. The top view in figure 61 shows the valve in its normal position. Only pressure lines connect to the top slide and only return lines connect to the bottom slide. The No. 1 power system serves the No. 1 subsystem units. The No. 2 power pressure and return lines connect to the No. 2 subsystems actuating pressure and return lines.

15-19. The bottom view shows the valve in the No. 1 Position. The slides connect the No. 1 power system pressure and return lines to *both* No. 1 and No. 2 actuating system pressure and return lines. The No. 2 power system pressure and return lines are both blocked. Power system pressure enters through line D. It goes out to No. 1 subsystem through line C and to the No. 2 subsystem through line B. Return flow from No. 2 subsystem enters through line G; return flow from No. 1 subsystem enters through line H. Fluid from both subsystems joins and goes out line J to the No. 1 power system return.

15-20. If the valve is placed in No. 2 Position, the slides are reversed and the action is reversed. Now, No. 2 power system pressure line (A) and return line (F) will serve both No. 1 and No. 2 subsystems. The purpose of snap-spring E is to hold the slides firmly in the positions they were placed in. Another selector valve like we discussed before is still required in each subsystem. It is needed to direct fluid to either alternating line in order to extend or retract the actuator. The selector valve in figure 61 does not do this; it merely selects the power source to be used.

15-21. **Variable-Restrictor Control Valves.** This type valve is generally limited to open-center systems designed to operate flight control surfaces. It is constructed so that movement of the cockpit control stick will cause a restriction of the open-center flow. The amount of restriction is determined by the amount of control stick movement. The restriction of the open-center flow causes a pressure buildup. The amount of pressure buildup determines the degree of control surface movement.

15-22. In position 1 of figure 62 notice that the two plungers (C and J) are in the neutral position. This allows fluid to enter inlet port F and flow unrestricted through the two variable openings (E and G). Then it flows through the two internal passages (B and K), and out through the return port (L). In position 2, the positioning arm (A) has been moved to the left, forcing the left-hand plunger (C) downward. When the plunger is forced all the way down, the variable opening (E) and the internal passage (B) are closed. Therefore, fluid entering the pressure inlet port (F) must pass through the right-hand variable opening (G). From there it goes out the alternating port (H) to the actuating cylinder. Return fluid from the actuating cylinder enters the alternating port (D), passes around the lower portion of the left-hand plunger (C). Then it goes up through the internal passage (K), and out the return port (L).

15-23. Position 3 of figure 62 shows the positioning arm (A) moved to the right, forcing the right-hand plunger (J) downward. The plunger blocks variable opening G and internal passage B. The fluid returning from the actuating cylinder enters alternating port H and passes around the lower portion of plunger J. From there it flows up internal passage B and out return port L.

15-24. In positions 2 and 3, we have shown the plunger completely blocking off variable opening E or G. This allows a maximum buildup of pressure in the open-center system. However, if the plunger is not completely depressed, openings E and G are not completely closed. This results in a limited pressure buildup in the open-center system, which in turn limits the control surface movement. The distance the control surface moves depends on: (1) the airload opposing its movement, and (2) the hydraulic pressure applied at the actuating cylinder trying to move the control surface. A low-pressure buildup in the open-center system results in a small movement of the control surfaces. A high-pressure buildup results in a large movement. Thus, the pilot can easily control the movement of the control surfaces.

15-25. **Electrically Operated Selector Valves.** There are two types of electrically operated selector valves—*solenoid operated* and *motor operated*. Solenoids are electrical devices that can be used to position mechanical units. Solenoids and motors permit us to position selector valves that are remotely located in the aircraft. Another advantage of electrical control is the removal of high-pressure lines from the cockpit. Furthermore, much weight is saved by the reduction of the length of hydraulic lines.

15-26. Solenoids have two positions that can be used when positioning a selector valve. One position is obtained by energizing the solenoid with electrical current. The other is the position assumed whenever the electrical current is shut off. This position is maintained by a spring.

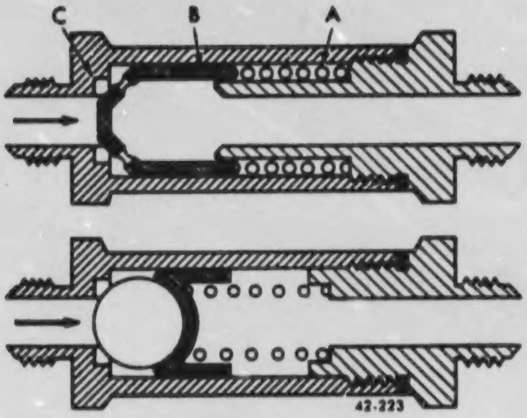
15-27. The motor also has two positions. It does not have to be energized in order to remain in either position. However, it must be energized in order to run to either position. The motor is a small high-speed type. It positions the selector valve through a set of reduction gears. When a valve is to remain in either position without the constant use of electricity, a motor will likely be used.

15-28. Since solenoids are faster operating and less expensive, they are more often used on aircraft. Many hydraulic installations require three-position selector valves. An example is in the landing gear system. If the valves are solenoid operated, two solenoids are used. When the landing gear is being retracted, one of the solenoids is energized. This one moves the selector valve to the UP position. When the gear is up and locked, neither of the solenoids is energized; the selector valve assumes the neutral position. During the extension of the landing gear, the other solenoid is energized; it moves the selector valve to the DOWN position. Some emergency means is provided for the pilot to lower the gear in case electrical power fails.

15-29. Single solenoids are sometimes used with two-position selector or control valves. The solenoid moves the valve to one position and a spring returns it to its original position. With this type of installation, no neutral position is provided.

16. Flow Control Valves

16-1. We are now going to study units that control the flow of hydraulic fluid in systems and subsystems. They control rate of flow, total quantity of flow and direction. They contribute much toward smoothness and efficiency of operation.



A. Spring
B. Cone
C. Valve seat

Figure 63. Cone- and ball-type check valves.

16-2. **Check Valves.** Check valves are installed in hydraulic systems to trap fluid under pressure in some part of the system. They do this by permitting free flow of fluid in one direction and no flow in the other. Typical examples of check valves are shown in figure 63. The top illustration shows the cone-type or sleeve-type check valve. As fluid pressure is applied in direction of the arrow, cone B is forced back off check valve seat C. This allows fluid to pass freely through the drilled openings of the cone. The bottom illustration shows a ball-type check valve. As pressure is applied, the ball moves back off its seat, thus letting fluid flow freely through the valve. The spring (A) holds the ball or cone on its seat whenever no fluid is flowing. The spring is very weak; it takes about eight psi to push it back far enough for full flow. When fluid attempts to flow in the opposite direction, the spring plus fluid flow seats the ball or cone. Thus fluid can flow in one direction only through the check valve.

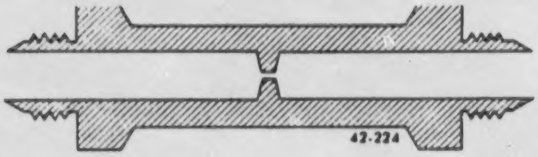


Figure 64. Fixed orifice.

16-3. **Orifices.** Orifices are often referred to as *restrictors*. They are used in systems to limit the speed of movement of such items as the wing and cowl flaps. They do so by serving as restrictions in the line; they limit the rate of fluid flow. Figure 64 shows the construction of a typical fixed orifice.

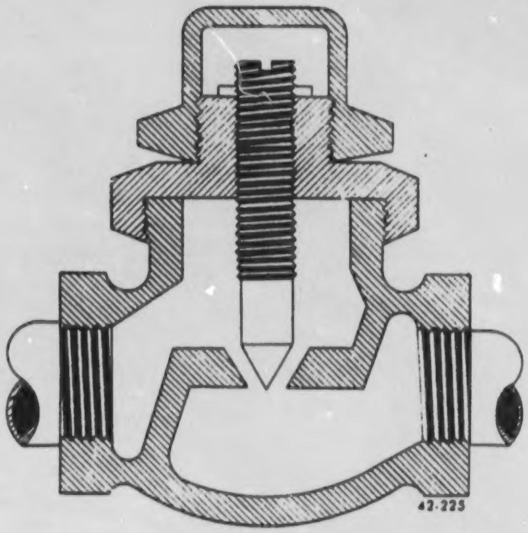
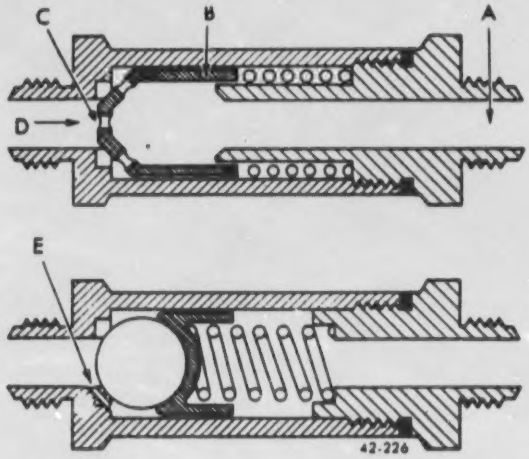


Figure 65. Variable orifice.

16-4. Other types of orifices are constructed so that the amount of restriction can be varied. The type shown in figure 65 is built so that you can alter the rate of fluid flow. It lets you adjust the speed or time of operation of a subsystem. Check your TOs for time requirements. Another type, similar to that shown in figure 65, has a handle on the top of the adjustment screw. It resembles a water faucet. This type can be used to control the speed of operation of such subsystems as windshield wipers. Frequently the type valve having the handle is referred to as a *globe valve* or *star valve*. It can be used to shut off fluid flow completely if desired.



A. Outlet port
B. Cone
C. Orifice
D. Inlet port
E. Orifice

Figure 66. Cone- and ball-type orifice check valve.

16-5. Now, of course, it seems logical to combine the orifice and the check valve. We next discuss this combination.

16-6. Orifice Check Valves. Orifice check valves are a combination of an orifice and a check valve. They provide the effects of both in a hydraulic subsystem. They allow normal speed of operation in one direction but limit speed in the other. Some typical examples of orifice check valves are shown in figure 66.

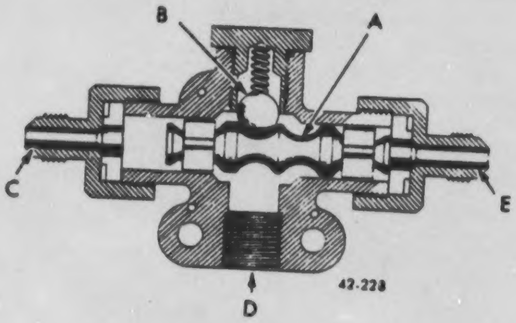
16-7. The top illustration shows the cone-type orifice check valve. Cone B is moved off its seat whenever enough fluid pressure is applied at inlet port D. This allows free flow of fluid through the valve and out A. Fluid flows through the valve in the opposite direction but is restricted by the size of orifice C. The bottom illustration of figure 66 shows a ball-type orifice check valve. Fluid flow through the valve from the left to right as shown by arrow D is normal; fluid flow through the valve the opposite way is restricted by the size of orifice E. The orifice is a drilled passageway located in the housing of the valve.

16-8. The orifice check valve is usually installed in the alternating line that carries fluid *from* the cylinder. It is in this direction of operation that slower movement is desired. It slows down the piston speed because fluid cannot escape from under it any faster than the orifice allows. To illustrate this, let's use the landing gear as an example. The orifice check valve is installed in the "up" alternating line. It allows the fluid to flow freely into the cylinder for rapid retraction of the gear. As the gear is extended, fluid leaving the cylinder must pass through the orifice. Thus, a cushioning effect results and the gear falls slowly, thereby preventing structural damage. If the restriction were placed in the "down" line, it would limit the quantity of fluid entering the cylinder and have no effect on the fluid leaving. This is not a good situation because the gear is heavy and tends to fall freely. As a result, a partial vacuum would be created in the cylinder, and the gear would fall too rapidly.

16-9. **Snubbers.** In most systems, reading the pressure gage is the best way to see if the system is working right. Some systems have warning lights for this purpose, but even in those cases there will probably be a gage. Two types of gages are used in most aircraft: (1) the direct-pressure type and (2) the pressure-transmitter type. The latter is electrically operated.

16-10. The direct-pressure type has a small fluid line running directly to a Bourdon tube in the gage itself. (This curved tube was previously discussed in Chapter 3 as operating a pressure switch.) The Bourdon tube is sensitive to the slightest change in pressure. This causes the needle to be moving almost constantly and makes it hard to read accurately. A dampening device, or *snubber*, is installed in the line leading to the gage and is usually positioned near the gage. The snubber smoothes out the variations in pressure so the gage reads the average of the fluctuations.

16-11. The snubber itself is merely an extremely small restrictor. The process of drilling tiny holes in steel is expensive and extremely difficult. Therefore, the snubber is made by drilling a large hole and inserting a pin into it. The tolerance between the hole and the pin provides the desired restriction. There is one important point to remember when you are installing the snubber in a gage line. You must bleed the air from the line between the snubber and the gage. If the air is not released, the gage will be inaccurate; there will be a time lag between pressure variations and the gage readings. Also, because air is compressible, the gage action will be sluggish.



A. Shuttle
B. Position retaining ball
C. Normal system inlet port
D. Cylinder port
E. Emergency system inlet port

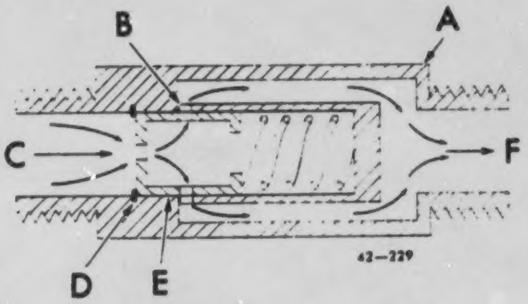
Figure 67. Shuttle valve.

16-12. **Shuttle Valves.** We usually say that the emergency system is completely separated from the normal system. This is true only up to a point. The emergency system uses a separate reservoir, pump, etc., but only one set of actuators is usually used to transmit power from either system. It is necessary to separate the normal system from the emergency system at the actuator, yet either system must operate when needed. The shuttle valve (fig. 67) serves this purpose. It is a small three-port unit with one moving part--the shuttle (A). The actuating cylinder port (D) is connected to one of the ports on the actuating cylinder. Either of the two remaining ports (E) or (C) may be connected to an alternating line from the emergency system selector valve. It is not necessary to operate all actuators in both directions during an emergency. Therefore, some actuating cylinders may have a shuttle valve attached to only one port.

16-13. Consider the landing gear actuating cylinders, for example. It is not necessary to retract the gear in an emergency. Therefore, a shuttle valve is needed only in the "down" port of the landing gear actuating cylinder.

16-14. In figure 67 the shuttle (A) is shown held to the right. Fluid coming from the normal system through port C has a path for flow out actuating cylinder port D. The spring-loaded ball (B) will hold the shuttle in this position indefinitely during normal operation. However, when normal system pressure is lost and the emergency system is operated, fluid enters port E. This forces the shuttle to the left, blocking port C. This prevents emergency fluid from escaping into the normal system. Now the emergency fluid has a path for flow into the actuator. The shuttle valve has satisfactorily separated the two systems.

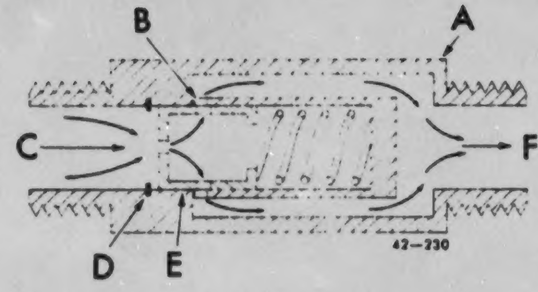
16-15. **Hydraulic Flow Regulators.** The flow regulator is sometimes called a *constant flow valve* or a *flow control valve*. As in the case with most hydraulic units, the name describes the function of the unit. Any one of its names tells us that its job is to keep the fluid flow at a constant rate. It does this in spite of changes in system pressure or actuator demands.



A. Body
B. Slots
C. Input port
D. Retainer
E. Piston
F. Output port

Figure 68. Hydraulic flow regulator -free-flow condition.

16-16. The flow regulator has only one moving part, the piston (E), as shown in figure 68. The valve regulates flow only from port C to port F. If it is installed backwards, it will not regulate. The body (A) of the valve is marked with an arrow to indicate the direction of regulated flow.

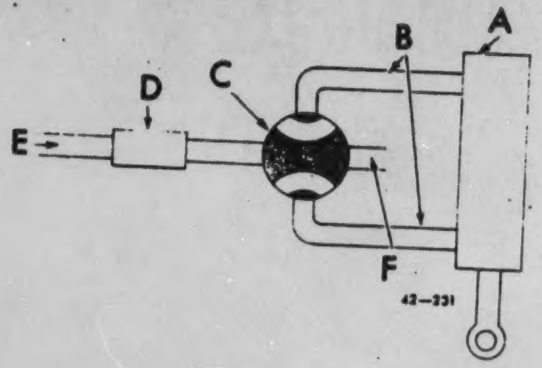


A. Body
B. Slots
C. Input port
D. Retainer
E. Piston
F. Output port

Figure 69. Hydraulic flow regulator—restricted-flow condition.

16-17. Operation of the flow regulator can also be seen in figure 68. Fluid enters the inlet port C, passes through the orifice in the head of piston E, and through piston slots B in the side of piston E. Then it passes out the output port (F). Any increase of pressure in port C will tend to increase the flow through the orifice in the head of piston E. But, the difference in pressure between the front and the back of the piston head will increase also. This pressure differential makes the piston move to the right, thereby compressing the spring. When the piston moves to the right, the slots (B) in the piston no longer line up with the holes in the regulator body (see fig. 69). This places an additional restriction on the fluid to keep it from flowing any faster. The piston can never move right far enough to completely block the ports in the side of the regulator body. Because, before this could happen the pressure behind the piston would become equal to the pressure in front of it. The spring then, will hold the piston to the left enough to keep the ports open. Retainer D limits the leftward movement of piston E.

16-18. An increase in pressure normally increases fluid flow through an orifice. But we see this is not the case with this flow regulator. As the pressure increases, the size of the openings for fluid flow at slots B decreases. This maintains a constant rate of flow. If the movement of the actuating unit calls for more fluid, the fluid flow starts to increase. An increase in demand by the actuating unit causes a decrease in pressure behind piston E. This causes the piston to move to the right, and therefore it decreases the size of slot opening B. This prevents an increase in fluid flow to the actuating unit. Thus, our flow regulator maintains a constant rate of flow. It does so regardless of variations in system pressure and regardless of the actuating unit's demands.



A. Actuating cylinder
B. Alternating lines
C. Selector valve
D. Flow regulator
E. Pressure line
F. Return line

Figure 70. Hydraulic flow regulator installation.

16-19. An example of typical flow regulator installation is shown in figure 70. System pressure enters at pressure line E. When selector valve C is positioned, fluid flows through flow regulator D. Thus, regardless of the selection, one of the alternating lines (B) will have regulated flow through it. This insures a smooth operation of actuator A, either way, at a *uniform* rate. Fluid returning to the reservoir goes through port F. These valves are available in different flow capacities and are rated in gallons per minute (gpm).

16-20. **Flow Equalizers.** The hydraulic flow equalizer is a unit that hydraulically synchronizes the movement of two actuating cylinders. Remember, synchronize means to move exactly together. To do this, it divides a single stream of fluid from the selector valve into two equal streams. Thus, each cylinder receives the same rate of flow, and both move in unison. The flow equalizer also combines two streams of fluid at an equal rate; therefore, it synchronizes the actuating cylinders in both directions. Since this unit equally divides and combines flow, it is said to be dual acting.

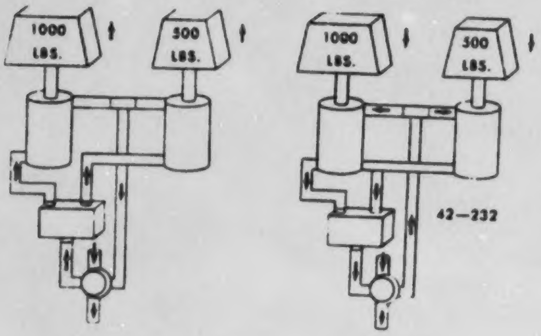
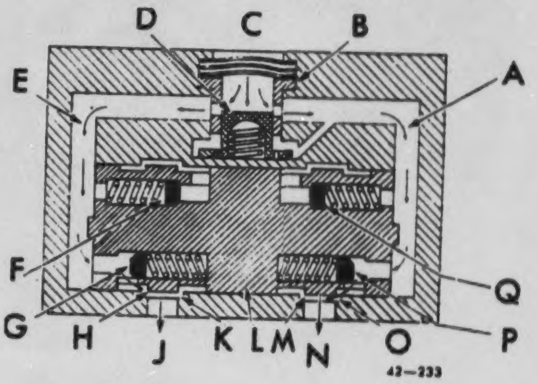


Figure 71. Flow equalizer installation.

16-21. Figure 71 shows how the flow equalizer synchronizes the movement of the actuating cylinders in both directions. In the left-hand picture the equalizer is splitting the flow to extend the pistons. The right-hand picture shows the valve combining the two streams coming from the cylinders as the pistons retract. The flow equalizer equalizes the flow, regardless of the pressure required to operate the actuators. Therefore, two cylinders with *unequal* loads will be properly synchronized.



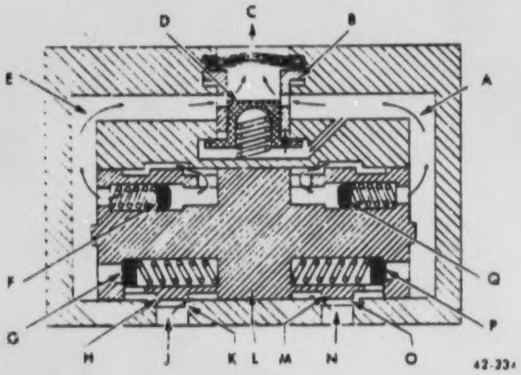
A. Side passage
B. Sleeve
C. Inlet port
D. Plug
E. Side passage
F. Combining check valve
G. Splitting check valve
H. Piston land
J. Left-hand exit ports
K. Metering groove
L. Free-floating metering piston
M. Piston land
N. Right-hand exit port
O. Metering groove
P. Splitting check valve
Q. Combining check valve

Figure 72. Flow equalizer—splitting position.

16-22. One type of flow equalizer is shown in figure 72. This type is used to divide the pump's fluid output into the two different systems.

16-23. In figure 72, the flow equalizer is shown in the splitting position. Fluid enters inlet port C, where it pushes down plug D and uncovers the two orifices in sleeve B. The fluid then splits and tends to flow equally down the two side passages (A and E). It then flows through the two splitting check valves (G and P) and metering grooves (K and O) in the valve body. Then it flows out the exit ports (J and N) to the actuating cylinders. Any difference in the rate of flow between the two passages results in a pressure differential between these passages. Then the free-floating metering piston (L) shifts to equalize the internal pressures, and the flow equalizes.

16-24. To illustrate this equalizing action, let's assume that the actuating cylinder attached to the left-hand exit port (J) moves easier than the one attached to the right-hand exit port (N). The fluid would then try to flow faster out the left-hand exit port, but in doing so it must also flow faster through the left-hand passageway (E). Fluid leaving exit port N meets with more resistance; so the flow down the right-hand passageway (A) is slower, and the pressure is greater than that of left-hand passageway (E). To explain this, think back to Chapter 1 to where you studied venturi tubes. There you learned the law of physics which states: As the velocity of a gas or liquid increases, there will be a corresponding decrease in pressure (against the walls of the tube). This momentary pressure differential forces free-floating metering piston to the left. This causes the space between piston land H and metering groove K to become smaller, which restricts the flow of fluid out the left-hand exit port (J). Thus, the flow equalizer imposes a restriction on the fluid that has a tendency to flow faster. This equalized the flow in the two streams.



A. Side passage
B. Sleeve
C. Inlet port
D. Plug
E. Side passage
F. Combining check valve
G. Splitting check valve
H. Piston land
J. Left-hand exit port
K. Metering groove
L. Free-floating metering piston
M. Piston land
N. Right-hand exit port
O. Metering groove
Splitting check valve
Q. Combining check valve

Figure 73. Flow-equalizer—combining position

16-25. In figure 73 the combining position of the flow equalizer is illustrated. This shows the units joining two streams of fluid at the same rate. Here the fluid enters the two ports (J and N) at the bottom of the valve. It cannot get through the splitting check valves (G and P). So it travels around the cylindrical-shaped metering piston and enters the combining check valves (F and Q) from the top. The pressure of the fluid opens the check valves and travels up the two side passages (A and E) to orifice sleeve B. The fluid pressure gets under sleeve B through a drilled passage and forces it upward. This uncovers the orifices and allows the fluid to flow out inlet port C.

16-26. Again for purposes of illustration, let's assume that the actuating cylinder attached to the left-hand exit port (J) moves easier. Fluid entering that port will then attempt to flow faster. But, as it leaves the check valves and flows up the left-hand passageway (E), it meets the restriction of the orifice. Therefore, if the flow momentarily increases, the orifice will cause an increase in pressure back through the left-hand passageway (E). This will force metering piston L to the right. This causes a restriction between metering groove K and piston land B. The fluid which tends to flow fastest has again been restricted.

16-27. **Hydraulic Fuses.** In the modern jet aircraft, the hydraulic system plays an important part in the flight operation. Some of the newest aircraft cannot fly without hydraulic pressure, the reason being that it is the sole power source for operation of the flight control surfaces. For this reason it is necessary to protect the system from complete failure.

16-28. If a system had no protective devices, complete failure could occur. A leak in any line or a blown seal in any unit might allow all the fluid to leak out. In combat aircraft, hydraulic boost operation of the flight control surfaces is most important. We don't want our entire system to become inoperative when one line has been shot away. We divide our system into sections so that a leak will not allow total fluid loss from the system. The sections are linked to the power section or each other through a hydraulic fuse. This valve limits the fluid loss to the amount contained in the small section of the system that is isolated.

16-29. As its name implies, this unit is similar to an electrical fuse. When too much current flows, the electrical fuse "blows" and opens the circuit. The hydraulic fuse stops the flow when a certain amount of fluid has passed through it. It actually measures the quantity of fluid that is flowing. That is why it is sometimes call a *quantity-measuring fuse*.

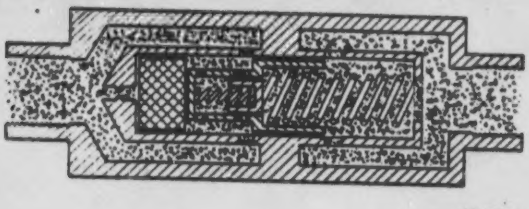


Figure 74. Hydraulic fuse—static condition.

16-30. Figure 74 shows a cutaway schematic of the hydraulic fuse in the static position. In this position there is no flow of fluid in either direction. This is the position the valve assumes whenever the system it protects is not in operation. When fluid is flowing however, it measures the flow from left to right. It cannot measure flow, neither can it act as a fuse if fluid flow is in the opposite direction. For this reason, hydraulic fuses are placed in the pressure line going to a subsystem selector valve. Otherwise, one must be located in each alternating line after the selector valve. Figure 75 shows these two methods of installing the fuse.

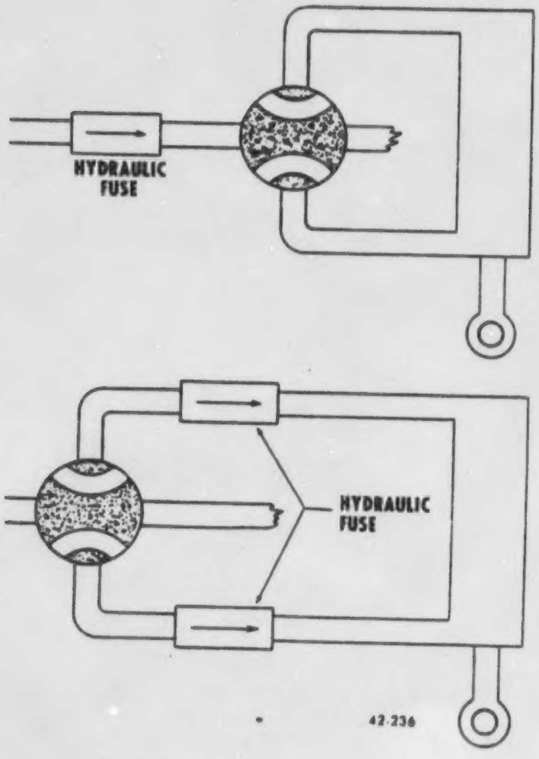
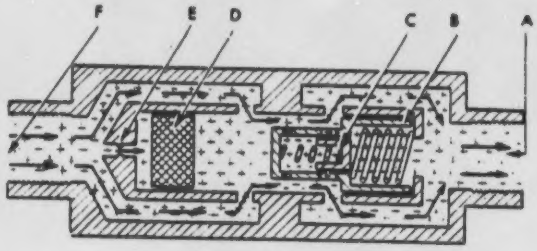


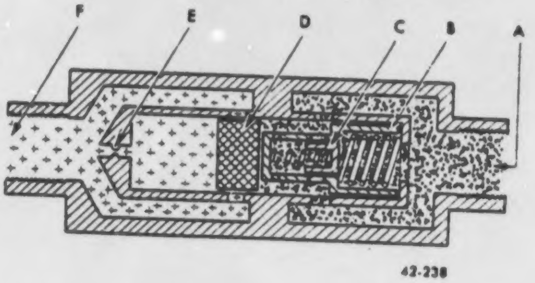
Figure 75. Hydraulic fuse installation.

16-31. In figure 76 we see the hydraulic fuse in the flow position. The fluid enters the inlet port (F). There it splits, flowing along the side passages and on to the center of the valve through the drilled holes. Here it pushes sleeve B back, letting fluid pass out the other holes, around the outside passages, and out the exit port (A). While this is going on, some of the fluid entering the inlet port (F) goes through the small orifice (E). This fluid *slowly* pushes piston D back. This happens because of fluid flow; there is less pressure on the back side of the piston than on the front. If more fluid flows than is normally required for one actuator operation, the piston will have moved all the way back until it hits sleeve B. (One normal operation will not move it that far.) In this position the piston blocks the holes drilled through from the outer passages. Now fluid flow from the exit port (A) stops. In this position the valve is fused, as is shown in figure 77. Remember, fluid flows through the fuse continuously until the piston moves back far enough to block the holes. Thus, the amount of fluid flow before the valve fuses depends upon the time it takes the piston to move to the right. If orifice E is large, the piston moves faster, allowing less fluid flow through the valve before it fuses. A small orifice causes the piston to move slower; this allows a greater volume of fluid to flow before the valve fuses.



A. Exit port
B. Sleeve
C. Check valve
D. Piston
E. Orifice
F. Inlet port

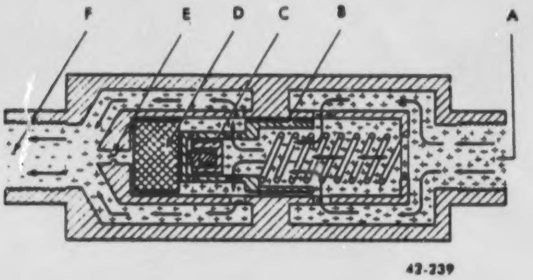
Figure 76. Hydraulic fuse—normal port.



A. Exit port
B. Sleeve
C. Check valve
D. Piston
E. Orifice
F. Inlet port

Figure 77. Hydraulic fuse—fused condition.

16-32. The size of orifice used depends upon the amount of fluid needed to move the actuator to its extreme travel. For instance, we have a landing gear actuating cylinder that needs 40 cubic inches of fluid for the piston to be fully extended. In this cylinder line we would install a fuse of about 45-cubic-inch capacity. We always us a fuse of slightly larger capacity than the actuator requirement. This insures that the valve will not fuse before the cylinder has reached its full limit of travel. Since the orifice cannot be removed from a fuse, we have fuses with different sized orifices. Each fuse has the flow capacity clearly marked on its body. Hydraulic fuses contain a check valve (C) to permit reverse fluid flow should the fuses be connected in alternating lines.



A. Exit port
B. Sleeve
C. Check valve
D. Piston
E. Orifice
F. Inlet port

Figure 78. Hydraulic fuse—reverse flow.

Figure 78 shows this reverse flow condition with the check valve open. During reverse flow the check valve (C) is pushed back to open side ports in sleeve B. Both sleeve B and piston D are pushed back to their original static position.

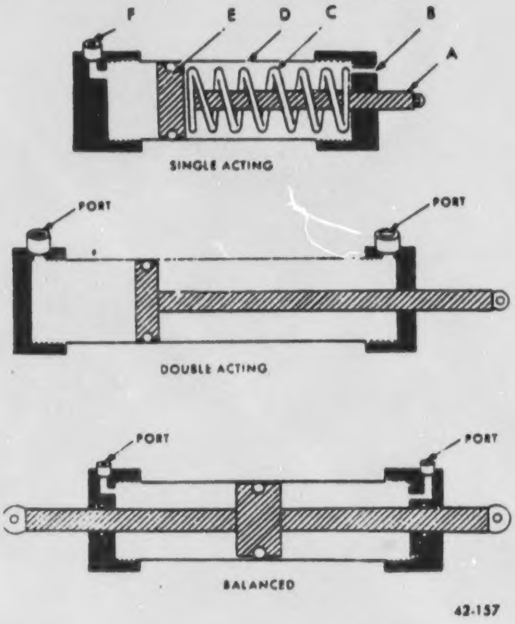
16-33. During normal operation the valve *nearly* fuses each time the full actuator capacity flows through it. When the fluid flow stops, pressure equalizes in all parts of the fuse. Then the large spring forces the sleeve and piston back to the static position. The fuse also "resets" to the static position when fluid pressure is relieved in the fused line.

16-34. If an alternating line bursts, or an actuator seal fails, the fuse allows its normal flow capacity to escape. At that time it fuses, preventing further fluid loss from the system. Although hydraulic fuses allow some fluid to escape from the system, enough remains to operate the other units.

16-35. **Maintenance of Control Valves.** Maintenance of control valves consists of disassembly, inspecting, testing, and repair or replacement of defective parts. After disassembly, inspect the pistons, cylinders, and sleeves for nicks and scratches that may cause leaks. As with all disassembled hydraulic components, the O-ring packings and gaskets must be replaced. When reassembling a control valve using two or more identical parts, each part must be put back in its original position. This is a "must" because these identical parts are mated (fitted) to their retainer. Remember also that work on all control valves must be done according to current overhaul TOs.

17. Hydraulic Actuators

17-1. The purpose of hydraulic actuators is to transform fluid pressure into mechanical force of action. This force can be exerted in a straight line or in a rotary direction. The direction depends on the type of actuators used. An actuating cylinder is generally used for straight line action, whereas hydraulic motors are used for rotary action. We covered hydraulic motors in Section 11, so we will now discuss only the cylinder actuators.



A. Piston rod
B. Vent
C. Spring
D. Cylinder
E. Piston
F. Pressure port

Figure 79. Types of actuating cylinders.

17-2. The units of an actuating cylinder, figure 79, consist essentially of a cylinder (D), a piston (E), one or two piston rods (A), ports, and the necessary seals. Actuating cylinders are usually double-acting; that is, fluid under pressure can be applied to either side of the piston so as to cause movement in either direction. Single-acting actuators with a spring return are used in some instances to actuate brakes and to charge machine guns. Balanced-type actuators are used to obtain the same amount of force in either direction.

17-3. **Single-Acting Actuating Cylinder.** The top drawing in figure 79 shows the single-port single-acting actuating cylinder. Fluid under pressure enters the pressure port (F) and moves the piston (E) toward the opposite end of the cylinder. In doing so, it compresses the spring (C). When the pressure is released, the spring returns the piston to its original position. Note that the chamber behind the piston is vented at B to permit free movement of air in and out.

17-4. **Double-Acting Unbalanced-Type Actuating Cylinder.** The second drawing in figure 79 shows the most commonly used type of a two-port actuating cylinder. These actuating cylinders are commonly used with landing gear, wing flap, speed brake, and cargo door systems. Fluid under pressure entering the right-hand port forces the piston to the opposite end of the cylinder. It thereby moves the mechanism attached to the rod. At the same time, the fluid ahead of the piston is forced out of the cylinder. It is returned through the selector valve back to the reservoir. If fluid under pressure is sent into the left-hand port, the direction of the piston is reversed. Fluid ahead of the piston is again forced out of the cylinder and returned to the reservoir. With this type of actuating cylinder, a mechanism can be moved in either direction. It is done by changing the direction of flow of the fluid as controlled by the selector valve.

17-5. Sometimes a mechanism requires more force to move it in one direction than the other. The double-acting *unbalanced* actuator will provide these unlike forces. Assume that the double-acting cylinder, shown in the center of figure 79, is a landing gear actuating cylinder. When the piston moves to the right and the piston rod moves out of the cylinder, the gear is raised. When the piston moves to the left, the gear is lowered.

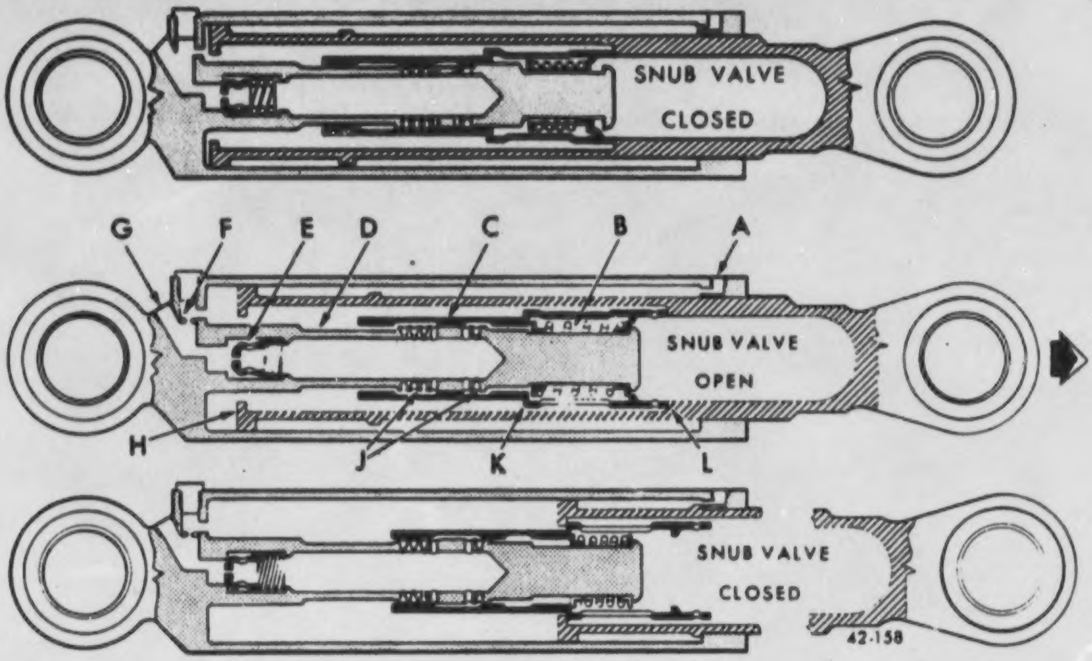
17-6. The reason for this construction is that a greater force is required to raise the gear than to lower it. The higher force is obtained by having the fluid act on the full area of the piston. Less force is obtained by the fluid's action on the smaller area of the rod side of the piston. The formulas in Chapter 1 regarding force, area, and pressure apply here. You can assume that the pressure entering either end of the cylinder is the same. Now apply the formula *area × pressure = force*. Accordingly, most force is against the side of the piston with the largest force area. In this case, it is the side opposite the piston rod.

17-7. **Double-Acting Balanced-Type Actuating Cylinder.** This cylinder, shown at the bottom of figure 79, is similar to the double-acting type. But in this case, the piston rod extends through the piston and out through both ends of the cylinder. One or both of these piston rods may be attached to a mechanism. In either case, the rods are used to provide equal areas on each side of the piston. Therefore, by the formula, with equal pressure we will get an equal force applied on each piston face. Also, the same quantity of fluid will move the piston the same distance either way. Control surface boost, nosewheel steering, and windshield wiper systems often use this type of actuating cylinder.

17-8. In recent years, the standard actuating cylinders, as those mentioned above, have been changed into more complex units. Snubbing and locking mechanisms have been built into the cylinder itself. An actuating cylinder with an internal snubber valve will be discussed first.

17-9. **Internal-Snubber-Type Actuator.** This type of actuator reduces damage to mechanisms due to rough handling. The snubber prevents the actuator from slamming into its end of travel with great force. Travel is slowed down when the piston nears either end of the cylinder. No external cushioning devices are required. Figure 80 is a typical example of an actuator with an internal snub valve assembly. The snub valve (D) is a chamber within the left chamber of the cylinder (fig. 80). Fluid can enter and leave the snub valve chamber through snub valve passageways (J) and the restrictor check valve (E). Most of the fluid that moves the piston either way must pass through this chamber. During the middle portion of the piston's travel this fluid flow is quite unrestricted. That means the piston, rod, and attached mechanism can move rapidly. But, as the piston reaches either end of its travel, the openings into the snub valve (D) chamber become restricted. This means the flow of actuating fluid through the chamber also becomes restricted. This slows down the speed of the piston at the end of its travel in both extend and retract mode.

17-10. Sleeve C and spring B are important parts of the snub valve. Notice, in each "Snub Valve Closed" view in figure 80, sleeve C blocks most of the J passageways. In the "Snub Valve Open" view, the J passageways are unblocked. When the J passages are open, the



A. Retract port
B. Snub valve spring
C. Sleeve
D. Snub valve
E. Restrictor check valve
F. Orifice

G. Extend port
H. Snub spring operator
I. Snub valve passageways
K. Snub spring operator shoulders
L. Snub spring operator

Figure 80. Internal-snubber-type actuating cylinder.

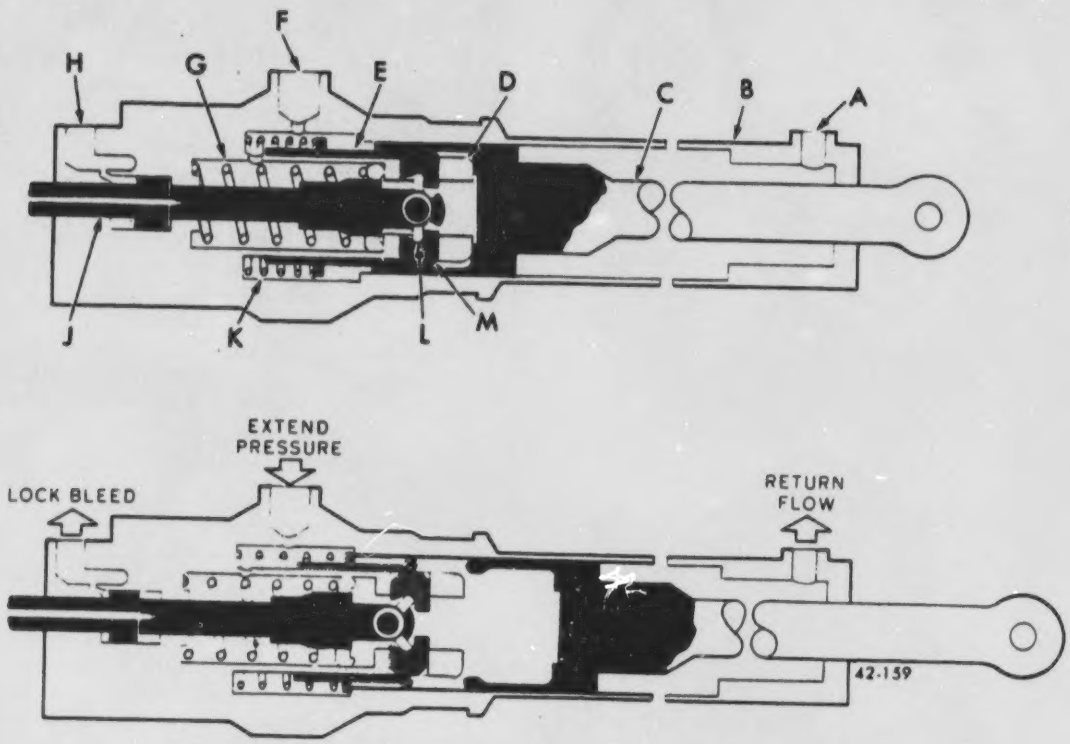
piston can move rapidly. When they are closed the piston moves slowly.

17-11. The top view of figure 80 shows the actuator fully retracted. Snub spring operator L (the shoulder) has contacted sleeve C and moved it to the left. In doing so, it compressed snub valve spring B. During the compression of the spring, sleeve C moved far enough to block the (J) passageways. This slowed the travel of the piston during the last part of retraction. Since port G is connected to the return line during retraction, restrictor check valve E is closed.

17-12. The middle view shows the actuator beginning to extend. Fluid pressure enters extend port G. Looking at the top view again, a small amount of fluid will pass through the orifice (F). Other fluid will push back the check valve (E), and a *small* amount will pass out the D chamber through the passageways (J). The combined force of the fluid going through the orifice (F) and the passages will start extending the piston *slowly*. When the piston has reached the point shown in the middle view, the (J) passages are wide open. Now there is full flow from port G, through the check valve (E), through the (J) passages and to the piston face. The piston now can move at full speed.

17-13. When the piston is almost fully extended, snub spring operator H (another shoulder) contacts shoulder K on sleeve C. This is shown on the bottom view of figure 80. As the piston extends the last distance, it pushes the sleeve to the right, thereby blocking the (J) passages. This immediately reduces the force acting on the piston because the actuating fluid is now restricted to orifice F. Because of the reduced fluid input the piston must slow down during this last fraction of its travel. The bottom view now shows the actuator at rest, fully extended. Notice that the final travel compressed spring B and closed check valve E.

17-14. Now retraction. Fluid pressure enters through the retract port (A). It exerts force on the opposite face of the piston and pushes the piston to the left. As the piston moves, the fluid in front of it must pass out through port G to the return line. With the (J) passages almost



A. Retract port
B. Cylinder
C. Piston
D. Retainer
E. Segment retainer
F. Extend port
G. Lock spring
H. Lock bleed port
J. Lock rod piston
K. Retainer spring
L. Toggles
M. Locking segment

Figure 81. Internal-lock-type actuating cylinder.

completely closed, the fluid must pass through the orifice (F) to escape. This orifice restricts the *first* flow of fluid and the piston travel to slow motion. However, as soon as the sleeve (C) moves left far enough (propelled by spring B), the (J) passages are opened. Now the major fluid flow can pass out through the chamber of D, through the orifice in the check valve, to port G. As a result, the piston speed increases.

17-15. When the piston reaches the point shown in the middle view, snub spring operator L again contacts sleeve C. The sleeve moves left and starts to block the (J) passages. This slows the piston, which ends up in the position shown in the top view—retracted. During extension, the actuator reduces speed by restricting input fluid. During retraction, speed is reduced by restricting outflow fluid. Notice the small openings in the extreme left end of the sleeve C; they connect the right end and the left end of the extend fluid chamber. The actuator (in this figure) produces more force when it extends than when it retracts.

17-16. An actuator with an internal locking mechanism will be discussed next. Such an actuator eliminates the need for a separate actuator for locking.

17-17. **Internal-Lock-Type Actuator.** Figure 81 shows a typical actuating cylinder (B) with an internal lock. This actuator will lock itself in the retracted position. The weight of any mechanism attached to the rod cannot extend the rod. In fact, the only way to unlock it is to apply fluid pressure to the extend port.

17-18. Here is how the piston locks. When fluid enters the retract pressure port (A), it pushes the piston (C) to the left. As it approaches the lock the lips of the hollow piston head enter the space between retainer D and the cylinder wall. See the lower view. As the lips slide in, they contact retainer E and push it back, compressing the retainer spring (K).

When the lips pass beyond the locking segments (M), the segments will spring up behind the lips. When the segments move outward they make more space for the toggles (L). The toggles can now take the vertical position as shown in the upper view. When the toggles move to the expanded position, the lock rod piston (J) can move to the right. The lock spring (G) pushes the lock rod piston to the right. There, it locks the toggles that in turn lock the segments that lock the piston. This action prevents the piston from being pulled out.

17-19. To unlock the piston and extend it, fluid pressure is sent into extend pressure port (F). The fluid flows into all chambers between the head of piston C and the head of lock rod piston J. Because it is locked, it cannot move piston C to the right. It can, however, push the lock rod piston (J) to the left while compressing the lock spring (G). When piston J moves left, it pulls toggles (L) partly out from between segments (M) and unlocks them. Now the lips of the piston (C), which are pulling to the right, can depress the locking segments and escape. As the lips slide over the segments to the left, the retainer spring (K) pushes the segment retainer (E) to the right. The retainer slides over the locking segments and holds them ready to accept the lips again when they return.

17-20. The lock bleed port (H) is connected to return in order to drain any fluid which might collect behind the lock rod piston (J). This prevents a fluid lock at this point. Also, the hollow stem of the lock and piston shaft can be used to attach a cable. This way the actuator can be unlocked manually by pulling on the cable, which might become necessary in an emergency or during ground operation. Such an actuator can be used in many hydraulically operated subsystems. It is ideal for hydraulically operated doors.

17-21. Oil Coolers and Supply Line Shutoff Valves. Oil coolers are used in hydraulic systems to keep the hydraulic fluid within a normal temperature range. The temperature range varies with the type of system they are installed in. The coolers are normally installed in the return lines of the system.

17-22. Construction of the coolers is similar to the automobile radiator. In fact, the coolers used on the F-4 aircraft are called radiators. Water flowing through automobile radiators is cooled by ram air as the vehicle moves down the road. Hydraulic fluid flowing through the oil coolers is also cooled by ram air. Another way of cooling the fluid flowing through the coolers is by installing the coolers in the fuel system. The heat of the fluid is absorbed by the coolness of the fuel.

17-23. Supply line shutoff valves are located in some aircraft hydraulic system supply lines leading to the engine driven pumps. These valves are electrically operated and are controlled by switches located in the cockpit. The valves can shut off fluid flow to the engine pumps in case of emergencies.

Landing Gear Components

THE LANDING speeds of aircraft are constantly increasing, particularly jet aircraft, which touch down on the runway at more than 110 mph. This increase has been brought about by the use of very efficient high-speed wings. However, these same wings have very poor lift characteristics, such as their tendency to stall and generally provide poor lateral control at low airspeeds. These conditions place severe loads on the landing gear and its components during each landing. To successfully complete any aircraft mission, the landing gear system must be in top notch condition.

2. Faulty gear retraction or extension, improperly operating shock struts, structural failures, or defective tires can cause serious damage to an aircraft. And still worse, these failures can cause injury or possible death to the crew. Therefore, you can see how important it is to understand the operation, maintenance procedures, and the inspections of landing gears and their components. You will be called upon to troubleshoot, locate defects, and repair units of the landing gear. Accordingly, this chapter is devoted to shock struts, shimmy dampers, and steering damper units.

18. Shock Struts

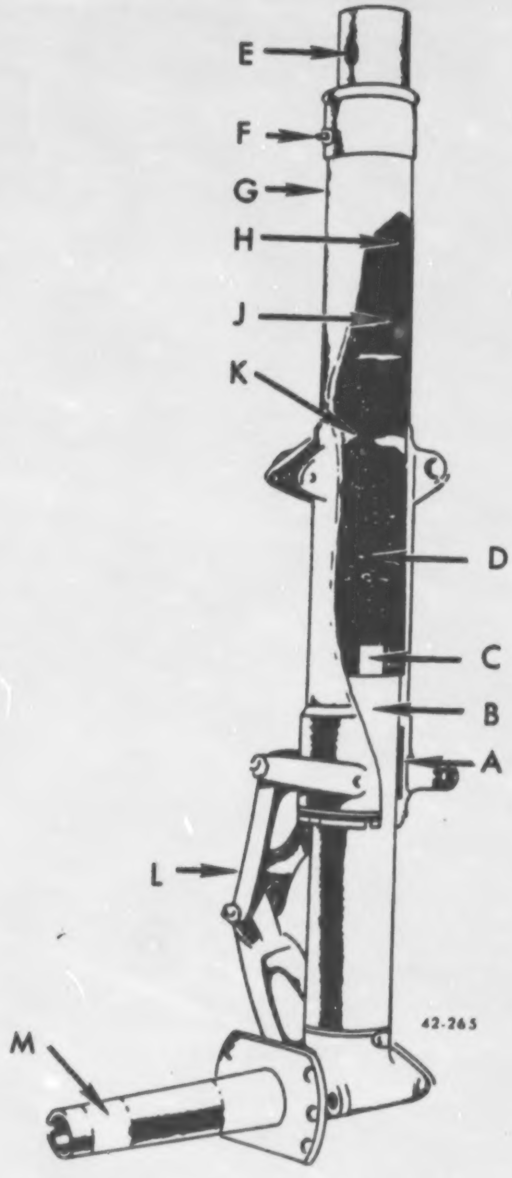
18-1. The most common type of shock strut is the air-oil strut. It contains hydraulic fluid and an air charge. A liquid spring shock strut that contains only liquid is in limited use. It depends upon compressibility of liquids and expansion of metal for its cushioning effect. Liquid flow in either type of strut is usually controlled by orifices or orifice check valves. The effect is that impacts and rebounds are "snubbed."

18-2. **Air-Oil Shock Strut Construction and Operation.** A basic air-oil shock strut assembly is shown in figure 82. The cylinder is divided into two chambers, a fluid chamber and an air chamber. The piston (C) or inner cylinder (B), which moves within the outer cylinder (G), is attached directly to the wheel axle (M). The torque arms (L), sometimes referred to as *scissors*, are attached to both the cylinder and the piston. This feature, found on all strut assemblies, prevents the piston from rotating within the cylinder. This is important because it holds the wheel in alignment.

18-3. Now study the operation of the strut assembly shown in figure 82. Notice the orifice place and orifice (K) within the cylinder. The orifice is one of the elements that helps to cushion the shocks. Also notice that chamber D, below the orifice plate, is filled with fluid. Chamber J, above the plate, is filled with compressed air (H). The cylinder part of the assembly is attached directly to the airframe at the strut support (E); therefore, it is stationary with respect to the aircraft.

18-4. Let's assume that the aircraft has just touched the ground during a landing operation. When the wheel strikes the ground, the piston and axle assembly moves up into the cylinder. Fluid is prevented from leaking past the piston because of the rubber (hydraulic) seals (A). These seals are installed on the piston head of some strut assemblies; on other struts they are installed within the cylinder walls. The fluid in the lower chamber (D) is forced up into the upper chamber (J) through the orifice (K). The compressed air in the upper chamber resists this action, which in turn aids in cushioning against the shock. However, compressed air alone is not sufficient to absorb the complete shock. Structural damage would probably occur were it not for the orifice (K), which divides the upper and lower chambers. We know that an orifice retards fluid flow. Resistance to fluid flow increases with the speed at which fluid is forced to move through the aperture. Therefore, the harder the impact, the greater is the tendency of fluid to rush through the orifice. This action increases the resistance, which combined with compressed air provides adequate cushioning effect.

18-5. The force exerted on the strut upon initial impact or when striking bumps exists for only a fraction of a second; but, during that time the piston has been thrust up into the

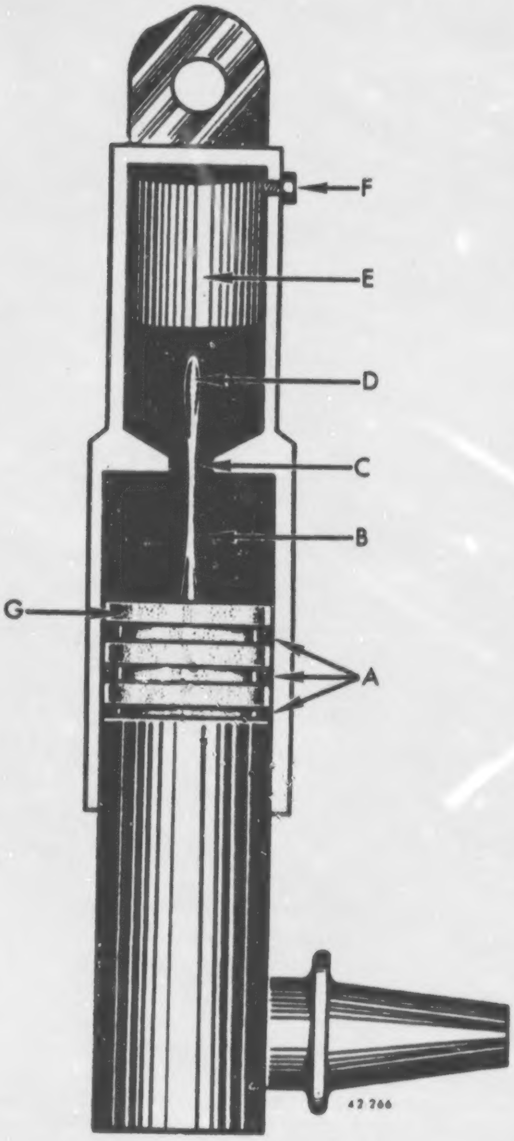


A. Hydraulic seals
B. Inner cylinder
C. Piston
D. Lower chamber (fluid chamber)
E. Strut support
F. Filler plug
G. Outer cylinder
H. Compressed air
J. Upper chamber (compressed air chamber)
K. Orifice
L. Torque arms
M. Wheel axle

Figure 82. Basic landing gear shock strut.

cylinder. When the force decreases, the compressed air forces the fluid back through the orifice. This causes the piston to return to its normal position in the cylinder. This cycle is continuous whenever the aircraft is taxiing. The distance the strut piston travels depends upon the intensity of the shock as determined by the condition of the terrain on which the aircraft is taxiing.

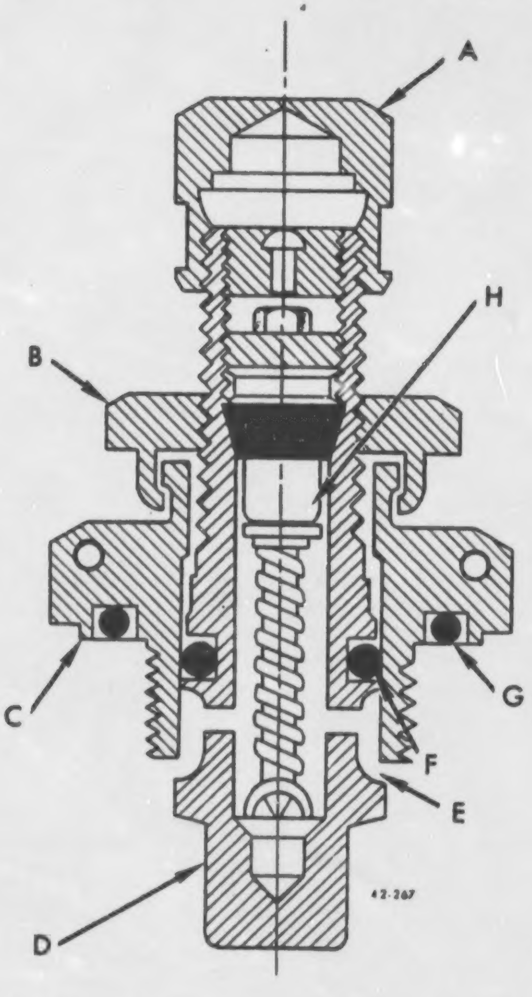
18-6. All air-oil shock struts work on the principle described in the above paragraphs (a combination of restricted fluid flow and compressed air). However, the method of restricting the fluid flow may vary.



A. Piston seals
B. Oil chamber
C. Orifice
D. Metering pin
E. Compressed air chamber
F. Filler valve
G. Piston

Figure 83. Use of metering pin in shock strut

18-7. One of the most common methods of restriction is by a metering pin and orifice plate. This is shown in figure 83. Just as the basic strut shown in figure 82, there is an orifice (C). The metering pin (D) moves with the lower part of the strut or piston (G). The pin is tapered at top and bottom. When the slender part of the pin is in the orifice, the restriction is the least. When the aircraft is parked under normal loads, the pin will be in this position. As the piston moves up or down, the thicker portion of the pin will reduce the size of the orifice. The movement increases the resistance to fluid flow gradually. This feature prevents hard bottoming of the piston. It slows down the movement smoothly but firmly as it nears the end of travel in either direction.



A. Valve cap
B. 5/8-inch swivel nut
C. Valve stem assembly
D. Valve core housing
E. Metal-to-metal seal
F. O-ring seal
G. O-ring seal
H. Valve core

Figure 84. High pressure air valve.

18-8. An orifice check valve is sometimes used in strut assemblies instead of the metering pin and orifice. It is generally referred to as the *recoil valve*. The inward or compression stroke of the piston is not affected by this valve. The valve is positioned so that fluid will flow freely into the upper chamber upon impact. But on the extension stroke the valve closes so that the fluid must pass through the orifice. The recoil valve decreases the oscillations of the strut piston. It also reduces the tendency of the aircraft to rebound.

18-9. **General Servicing Instructions for Air-Oil Shock Struts.** You have become more familiar with the general construction and operation of shock struts. So next we discuss some of the maintenance required to keep them in top working order. Leaks may occur in the air-oil shock struts. Therefore, you must periodically check the fluid level and replenish the supply. The filler plug is shown as item F in figures 82 and 83. If fluid has to be added, release *all* the air pressure in the strut. Improper deflation of shock struts is highly dangerous; use definite precautions and procedures.

18-10. Remove all stands, jacks, and obstructions from under the aircraft. They could cause damage when the aircraft is lowered. Make sure all personnel are clear of the aircraft. This is to prevent the possibility of injury in case of a sudden collapse of the strut. You must know the type of air filler valve used when servicing shock struts. Two types of valves are being used on aircraft struts. Each type requires a slightly different procedure when servicing the strut. The applicable technical order should be consulted before any attempt is made to deflate the strut.

18-11. Figure 84 shows the type of valve (AN6287–1) used on many of our aircraft. To depressurize a strut using this valve, first remove the valve cap (A). Next, turn the 5/8-inch swivel nut (B) to the left up to one complete turn, but no further. This lowers the valve core housing (D) to break the positive metal to metal seal (E). There are nonmetal type seals at F and G. Excessive loosening of the swivel nut will result in dropping the valve core housing (D) into the strut. Now, release the air by depressing the stem of the valve core (H). After all pressure is bled off, remove the entire valve stem assembly (C) from the strut. This provides a hole for checking the fluid level in the strut and for adding hydraulic fluid when needed.

18-12. As mentioned before, another type of valve assembly is also being used. The main feature of this valve (type MS28889) is that it doesn't have any valve core. This valve assembly looks much like the one shown in figure 84. You can easily recognize the MS28889 valve by the size of the swivel nut. This swivel nut is the same size (3/4 inch) as the body nut. To depressurize struts equipped with the MS28889 valve, loosen the swivel nut (upper) about three-fourths of a turn. This allows the air to discharge. After all air is bled off, the valve assembly may be removed for servicing procedures.

18-13. Regardless of the type of valve used, *never* loosen the valve body (lower nut) when the strut is pressurized. This can allow the whole valve assembly to be blown off, which could easily result in serious injury to personnel and equipment. Another safety precaution is to never remove the valve core when the strut is pressurized. The valve core could be blown out with the velocity of a bullet.

18-14. In servicing (adding fluid and air) shock struts, two different procedures are now used. One procedure is used for hard struts and another for soft struts. Hard-strut servicing is the procedure that you will find most commonly used. Of course, you should consult the applicable TO for specific servicing instructions.

18-15. *Hard-strut servicing.* Assume that we have completely depressurized the shock strut. The strut is now fully collapsed, and an inspection shows that the strut is low on hydraulic fluid. Remove the valve assembly and fill the strut to the level of the valve hole with hydraulic fluid. Reinstall and securely tighten the servicing valve. Lock the valve with the specified size and type of safety wire.

18-16. To charge the strut with air, first make sure that the swivel nut (item B, fig. 84, or the upper 3/4-inch nut of the MS valve) is loosened about one turn. Inflate the shock strut so that it extends to the specified distance. Then tighten the swivel nut to the torque specified in the technical order. Under certain conditions the hard-strut-type servicing has one disadvantage: with a heavy load and especially on *very* hard landings, the strut piston can bottom. That means, it compresses the air enough so that it hits the piston's positive metal stop. This can structurally damage the gear. To offset this possibility, soft-strut-type servicing is used on some aircraft. Also, later struts are modified to reduce possibility of bottoming.

18-17. *Soft-strut servicing.* When using this method also fill the strut with fluid to the level of the filler hole. However, only 450 psi of air is pumped into the strut. Such a pressure will give little or no strut extension. Then hydraulic fluid is pumped into the strut under pressure to provide the desired strut extension. This extra hydraulic fluid prevents the piston from ever reaching its upper travel limit (positive metal stop) during hard landing. Soft-strut servicing is not used very much. Your aircraft TO will tell you under what circumstance to use it.

18-18. Whether you are using hard struts or soft struts, the aircraft wings should be rocked while you pump up the strut. This helps eliminate any binding that might take place between the piston and the strut cylinder. It permits proper extension and prevents overinflation. The aircraft TO will tell you on what rare occasions soft strut servicing is required—usually Arctic conditions.

18-19. *Nose gear shock strut depressurization valve.* The air pressure in some nose gear shock struts is reduced after the aircraft is airborne. This is done by a mechanically operated depressurization valve while the nose gear is being extended. This reduction in air pressure results in a more nose-down attitude upon landing. It offsets a tail-heavy condition that results from a change in the center of gravity because of fuel consumption. This type of installation requires that the shock strut be serviced with air after each landing.

18-20. **General Maintenance Instructions for Air-Oil Shock Struts.** You now know something of the construction, operation, and servicing of air-oil shock struts. So here we discuss some general maintenance instructions common to all air-oil shock struts. Available facilities determine the extent of work that base shops perform on shock struts. Some shops have the facilities to only replace seals. Others have the facilities to perform a complete overhaul. If your shop has overhaul facilities, the following discussion should help you. Even if you do not have these facilities, the knowledge will advance you in your career field. Keep in mind that the following is general information. You need to go to applicable TOs for more specific directives.

18-21. *Maintenance of installed shock struts.* The most important job on installed shock struts is keeping the exposed portion of the pistons clean. Strut pistons are chromeplated, but they should nevertheless be wiped clean after each flight. Dirt or grit on the piston can scratch the piston or cut the seals. Scratches and cuts, in turn, can cause leakage past the seals.

18-22. *Maintenance precautions to be observed while disassembling shock struts.* Observe the following general precautions when you disassemble shock struts. Of course, for specific directives you must follow the instructions in the applicable TO.

a. Before disassembly, double-check to insure that all air pressure has been released from the strut. After you are sure that all the air is removed, drain all fluid by hanging the strut upside down. If practical, move the piston through its stroke a few times to insure that all fluid is removed.

b. Use brass, bronze, copper, plastic, or leather-faced tools, to eliminate the possibility of damage to polished surfaces when working on the strut.

c. All holding jigs, fixtures, and vises should be covered with felt, copper, or a suitable equivalent.

d. Mated parts should be marked for identification with a removable parts tag at time removal.

18-23. *General cleaning instructions.* Clean aluminum parts of struts by immersing them in a solution of trichlorobenzine from 10 to 20 minutes. It is important to remember that this solution is toxic. Therefore, maintain a 4- to 5-inch water seal at all times on top of the solution. You can easily measure water depth by inserting a transparent tube slowly into the solution and then holding the upper end closed while withdrawing the tube. The solution must also be vented to the atmosphere.

18-24. Immerse steel parts in a solution of electroplater's cleaning compound from 1 to 5 minutes. Do not allow aluminum parts to contact this solution. Parts that contain both aluminum and steel must be soaked in "Formula T" solution from 5 to 15 minutes.

18-25. After cleaning, rinse, dip, or spray all parts (aluminum and steel) with cold water. This is followed by a hot water dip from 2 to 4 minutes. The parts are then ready for inspection.

18-26. *General inspection and repair instructions for disassembled shock struts.* Examine chromed surfaces of the cylinder for scratches, scores, blisters, and nicks. Such defects can cause excessive wear of the seals, thus producing the eventual failure of the strut. All suspected defects should first be tested to determine if the base metal has been exposed. For this, you liberally apply a copper sulphate solution to the suspected area. (This solution consists of 100 grams of cupric sulphate, 5 milliliters of sulphuric acid, and 1 liter of water.) Then wipe off excess fluid and inspect the part under a strong light and magnifying lens. A copper coating will show on the iron metal where the chrome plating has been removed. The strut must be replaced if this condition exists. If the chrome is not penetrated, hone or polish defects. This is to remove all sharp edges that could damage the seals. The strut will be replaced if defects in plated areas exceed the following:

- Scratches, scores, and pits that have penetrated the chrome plating.
- In working area of seals, two scratches, up to 4 inches long and 0.002 inch deep, in any one inch.
- Pits of 0.002 inch in depth regardless of diameter.
- Two pits, less than 0.002 inch in depth, in any given square inch.
- Cracks, regardless of size or location. (Inspect all ferrous (iron) parts for cracks and flaws by the magnetic particle method. Inspect all nonferrous parts for cracks and flaws by the fluorescent or dye penetrant method. Your nondestructive testing laboratory will perform these checks.)

18-27. Measure all bushing and friction surfaces to insure that they are not worn beyond tolerance. Inspect all bronze and brass trunnion bearing surfaces for nicks and burrs and dress all defects carefully. Use a fine-tooth file. CAUTION: Never use emery cloth or sandpaper, since particles of grit will penetrate and remain in the bearing surface.

18-28. When reassembling the strut, replace all O-ring packings, gaskets, and backup rings. Use Teflon backup rings when available. Lubricate all packings, gaskets, and grooves with grease, MIL—G—4343. When V—rings are used, install them one at a time to make sure that the feathered edges are not damaged.

18-29. *Corrosion treatment of shock struts.* The exposed portion of the shock strut is cadmium plated and/or painted to prevent corrosion. If these coatings are removed or damaged, repair them by applying two coats of zinc chromate primer. Follow this with two coats of aluminum lacquer (12 ounces aluminum paste and 1 gallon clear cellulose lacquer). Apply this to large areas by spraying and to small areas with a brush. Replace name and data plates which are destroyed or unreadable. Use standard plates if new manufacturer's plates are not available.

18-30. *Leakage test of overhauled shock struts.* Bench test all overhauled struts before returning them to stock or putting them on aircraft. Since there are many types of struts, there may be many different ways to test them. Therefore, check your TO for specific testing procedures. But, the following is general information which can be applied to all air-oil struts.

18-31. The leakage test is performed in two steps: The first step is the HIGH pressure test, and the second is the LOW pressure test. The chart in table I is the typical of the proper values. Check the TO for specific values. Pressurize the strut with test equipment, using MIL—H—6083A or MIL—H—5606 fluid, or a 50—50 mixture of each. The strut can be in either a vertical or horizontal position while under test. Conduct a thorough inspection at each pressure (HIGH and LOW) and give particular attention to packings and gaskets. Any leaks are cause for rejection. Use of air pressure (only) to pressurize the strut is prohibited, unless specifically authorized by TO. This prevents the possibility of introducing moisture into the air and oil chambers. Such moisture might bring on corrosion later. After the tests have been completed, the strut should be filled with MIL−H−6083A preservative fluid.

TABLE I
TEST PRESSURE VALUES

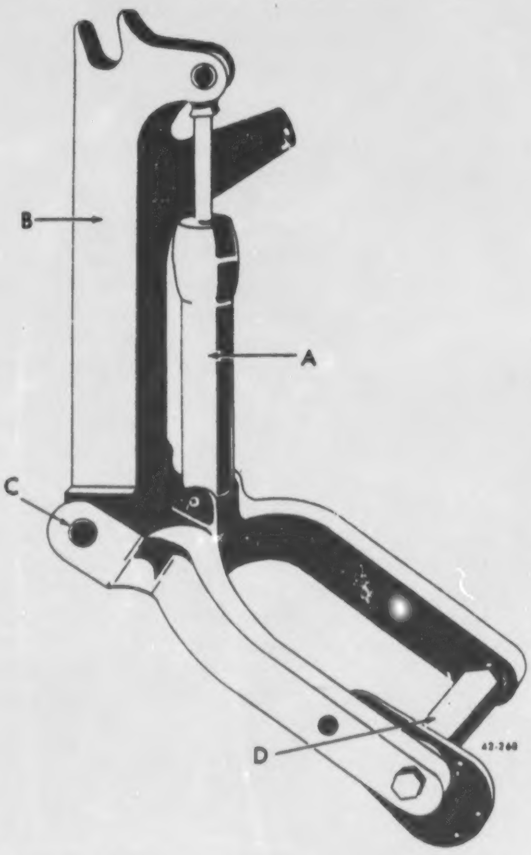
18-32. *Preparation and packaging of repairable struts.* We said before that available facilities determine where shock struts are overhauled. If the strut is to be sent to depot for overhaul, it must be properly prepared for storage. Even though the strut is to be overhauled at base shop, it may still have to be prepared for storage. This depends on how soon after removal the strut is to be overhauled.

18-33. The first step to prepare a strut for storage is to clean all external ferrous metal surfaces. Use P−S−661 cleaning solvent and dried compressed air or wipe dry with clean dry rags. Immediately coat all unpainted external surfaces with corrosion-preventive compound, MIL−C−17173A, Grade A. Parts such as axles, joints, brake flanges, and torque arms all have surfaces requiring this treatment. Grease all fittings to prevent corrosion under collars, bushings, etc. Chrome-plated parts should also be treated to prevent entry of moisture through plated surfaces. Parts can be further protected by being wrapped with greaseproof barrier material, JAN−P−127, Grade A.

18-34. In addition to corrosion treatment, the proper use of containers is also important. The container for each strut protects it from damage. Also, it protects against exposure to adverse weather conditions. Proper handling of these containers cannot be emphasized too strongly. You should exercise caution when opening or closing containers by using proper tools to prevent damage. Always insure that the strut fits snugly into the cradles and mounting blocks.

18-35. **Liquid Spring Shock Struts.** The liquid spring shock strut has no air in it to be compressed. This strut depends primarily upon the compressibility of its fluid for its cushioning action. From the compressibility of the liquid we get the name "liquid spring."

18-36. This shock strut has limited use. At present, it is found on only one model of the Century series of fighter aircraft. Although there is no need for you to have much knowledge of such a type of device, we do feel that you should know that such a strut exists. You should also know a little of how it works in case some aircraft designer uses it again.



A. Liquid spring unit
B. Gear frame
C. Fulcrum
D. Wheel spindle

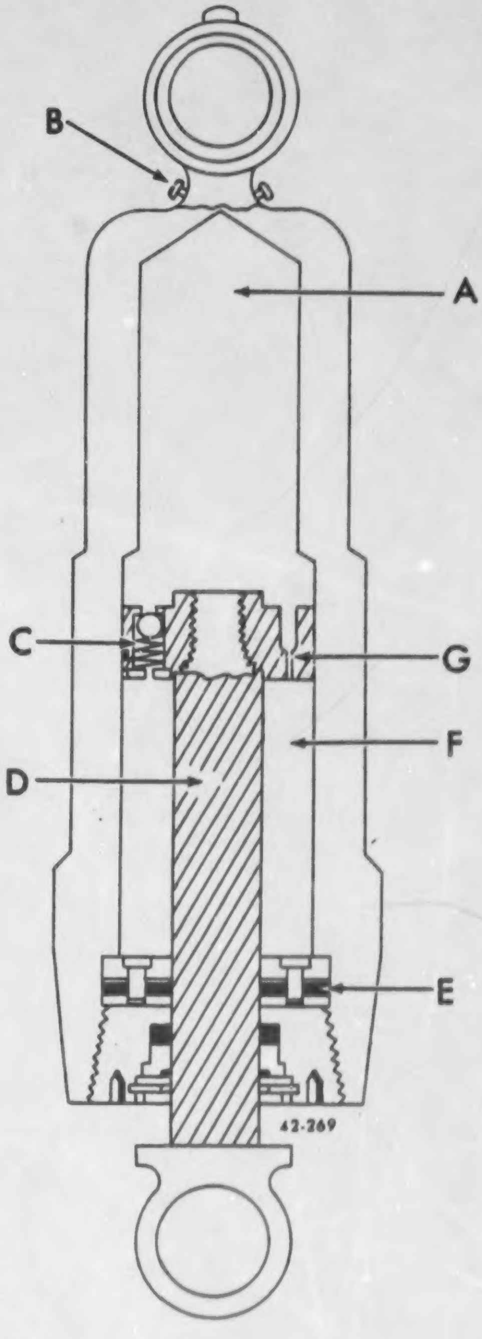
Figure 85. Liquid spring strut.

18-37. The idea of compressing a liquid may surprise you. We have always said that for all practical purposes liquids are incompressible. And, it is still true—in the ranges in which hydraulic systems, jacks, and presses operate. It is when you get up into the 20-, 30-, and 40-thousand psi ranges that strange things happen. Different liquids do different things. Even our scientists don't know what all may take place at these pressures. One physics book states that water has no minimum volume at pressures over 35,000 psi. The pressure in the liquid spring strut of an average size fighter standing still is about 20,000 psi. On landing or taxiing it may go as high as 45,000 psi.

18-38. Figure 85. shows a typical liquid spring installed on an aircraft landing gear. The frame is item B in the figure. Notice the distance between the wheel spindle (D) and the fulcrum (C). Compare it to the distance between the liquid spring unit's (A) lower attachment point and the fulcrum (C). Comparing the two distances as arms of a lever gives the mechanical advantage (MA). The aircraft weighs several tons. This weight on the wheels exerts a tremendous force on the piston of the liquid spring unit. It is enough to compress the fluid slightly.

18-39. The type of liquid used affects the operation of the liquid spring strut. Different liquids have different compressibility factors. The type of liquid used in the liquid spring strut is specified in the applicable TO. This strut requires a silicone-based hydraulic fluid. It is an exotic and expensive liquid.

18-40. Figure 86 shows a cutaway schematic of the liquid spring actuating unit. Let's see how the unit operates internally. Just before landing, the piston rod is in a fully extended position. When the wheels touch the runway, the shock is transmitted to the piston rod (D). The piston and rod assembly is forced upward. This movement displaces liquid from the upper chamber (A) to the lower chamber (F). The liquid is forced through the orifice check valve (C) and the orifice (G). The lower chamber (F) can accommodate only a part of the liquid being displaced. The rod occupies some space in the lower chamber. So pressure in both chambers increases greatly, and the liquid is compressed as the piston travels upward. Because of the MA involved, long travel of the spindle (D) (fig. 85) creates a short but powerful stroke of the piston. When the piston rod starts to extend on the rebound stroke, liquid from the lower chamber (F) flows to the upper chamber (A). It must go through the fixed orifice (G). The orifice check valve (C) is closed at this time. Because the liquid flows through the fixed orifice only, the rebounding is "snubbed." Thus, the bouncing that often occurs after landing is held to a minimum



A. Upper chamber
B. Filler plug
C. Orifice check valve
D. Piston rod
E. High-pressure gland
F. Lower chamber
G. Orifice

Figure 86. Cutaway schematic, liquid spring strut.

18-41. Another major factor should be mentioned—the expansion of the cylinder housing when the internal pressure is increased. Any time the piston is forced upward into the cylinder, the pressure increases. This causes the walls of the cylinder to stretch slightly and expand in an outward direction. This, in turn, slightly increases the cylinder volume Therefore, the piston can move up farther than it would otherwise when the impact of landing is placed on the piston rod.

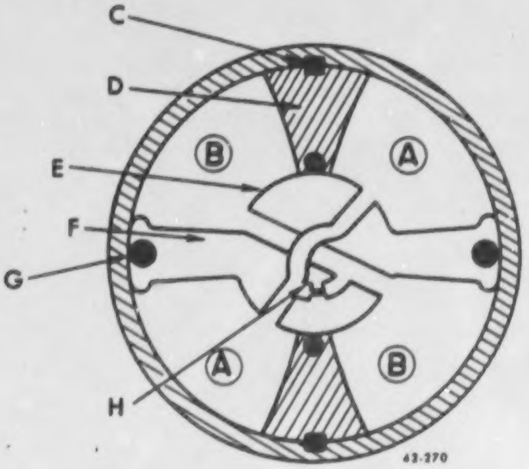
18-42. Field maintenance of the liquid spring strut is much simpler than with the air oil struts. This is primarily because of the simple construction of the unit. It is also simpler because of the specially designed high-pressure gland (E). This high-pressure gland is designed so that it can withstand pressures up to 60,000 psi. Such a gland permits practically no oil leakage. When additional liquid is needed, it is applied through the filler plug (B). The proper extension is determined by the initial hydraulic pressure pumped into the strut. When filling, the weight of the aircraft must be off the gear, and the strut must be fully extended. Around 800 psi initial pressure is generally needed when filling the strut. This requires a high-pressure oil gun. Also, extreme caution should be used because of the unusually high pressures in the cylinder; *follow the TO instructions* when you service this equipment.

19. Shimmy Dampers

19-1. Practically all modern aircraft have nose gear. It is easier to steer and taxi aircraft with nose gear than one with a tail wheel. Have you ever driven an automobile that had a severe shimmy in the front wheels? Aircraft nose gear assemblies have an even greater tendency to shimmy. This shimmy adds to the possibility of structural damage to the gear or even complete failure. Obviously, such a condition is dangerous and should be prevented.

19-2. Alignment and balance of the wheels is important in doing away with shimmy. But, shimmy dampers or snubbers are also necessary. They are used with nose and tail wheels to prevent oscillation or shimmy during landing, takeoff, and taxiing. At the same time, they permit the wheel assembly to turn or "tract" as the aircraft turns when taxiing. Some aircraft use steering damper units that give both a damping action and hydraulically powered steering control. It is easy to design a shimmy damper into a steering damper unit. The design and principle of operation is much the same for both.

19-3. Nose wheel dampers are either the vane type or piston type. Both work on the idea that the resistance of an orifice to fluid flow increases with an increase in speed of the fluid. Application of this principle permits slow turning movement of the nose wheel when steering. But, it also offers high resistance to sudden movements or oscillations due to shimmying.

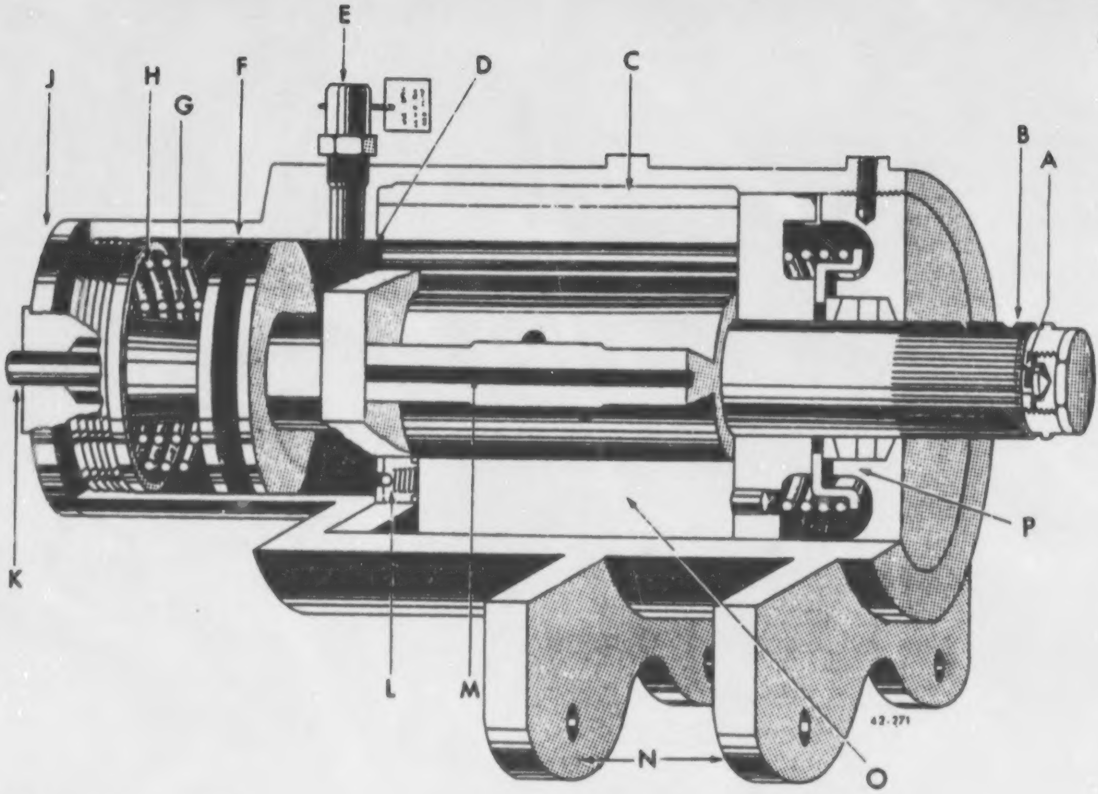


A. Chamber
B. Chamber
C. Flange keys
D. Stationary vane
E. Wingshaft
F. Movable vane
G. Hydraulic seals
H. Orifice

Figure 87. Shimmy damper vane arrangement.

19-4. **Vane-Type Shimmy Dampers.** An internal view of this type of damper is shown in figure 87. This unit consists basically of a working chamber, two stationary vanes (D), and two movable vanes (F). The movable vanes and the stationary vanes divide the interior into four chambers (A, A, B, and B). The two movable vanes are connected to the wingshaft (E), which extends to the outside of the assembly. The wingshaft is attached through splines to a mechanical linkage which, in turn, connects to the nose wheel. When the nose wheel turns, the wingshaft swings the movable vanes.

19-5. Notice that both chambers A are interconnected and, likewise, both chambers B are interconnected by channels. These two channels are connected to each other through a small orifice (H). Now, how does this thing work? Assume that the movable vanes (F) are being turned clockwise. Both chambers B will decrease in capacity and chambers A will increase. This forces fluid from chambers B into chambers A through the orifice (H). The orifice restricts this flow, thereby damping or slowing the movement of the wheel and preventing shimmy. When the wheel tries to turn counterclockwise, the action is the same; except now the capacity of both chambers (A) decreases and chambers B increase. Again fluid is forced through the orifice but in the opposite



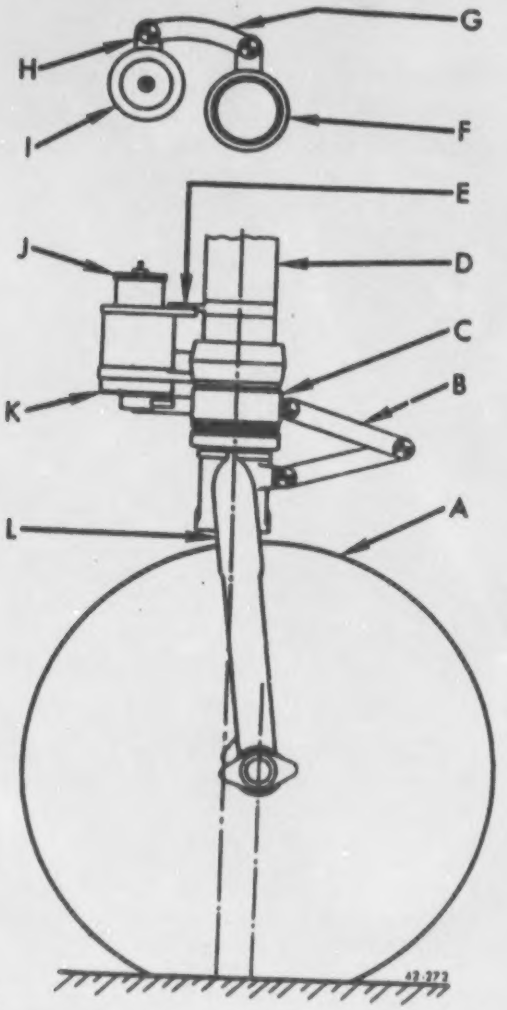
A. Orifice valve adjustment
B. Wingshaft
C. Flange key
D. Reservoir
E. Filler fitting
F. Replenishing piston
G. Inner piston spring
H. Outer piston spring
J. Reservoir cover
K. Indicator rod
L. Replenishing valve
M. Rotating vane
N. Mounting lugs
O. Stationary vanes
P. Wingshaft packing, retainer, and spring

Figure 88. Cutaway view of vane type shimmy damper

direction. Again, resistance develops. Flange keys (C) prevent the stationary vanes from rotating within the housing. Hydraulic seals (G) prevent leakage between the chambers.

19-6. Figure 88 shows a cutaway view of the vane-type shimmy damper. The wingshaft (B) shows splines by which the linkage is attached to the wheel fork. The flange key (C) holds the stationary vanes (O) rigid to the outer case. It is through the filler fitting (E) that fluid is forced into the reservoir (D). A pressure gun is required to fill the reservoir because the replenishing piston (F) holds the reservoir under pressure. Inner and outer piston springs (G and H) apply force to the replenishing piston. An indicator rod (K) is attached to piston F and extends out through the reservoir cover (J). It shows how full the reservoir is. The replenishing valve (L) permits fluid to be forced from the reservoir into the main chamber if it leaks. A hydraulic seal is shown between the movable vane (M) and the case. A similar seal is found between the stationary vanes and the wingshaft. Mounting lugs (N) attach the damper to the stationary strut cylinder. The packing, retainer, and spring (P) prevent leakage of fluid past the wingshaft. The spring applies pressure on the packing. The size of the orifice between the chambers is adjusted by rotating the adjusting screw (A) in the end of the wingshaft. If the orifice opening is too large, the damping effect is reduced. If too small, it interfers with the normal tracking of the wheel. The adjusting screw is protected by a capnut which is removed for adjusting.

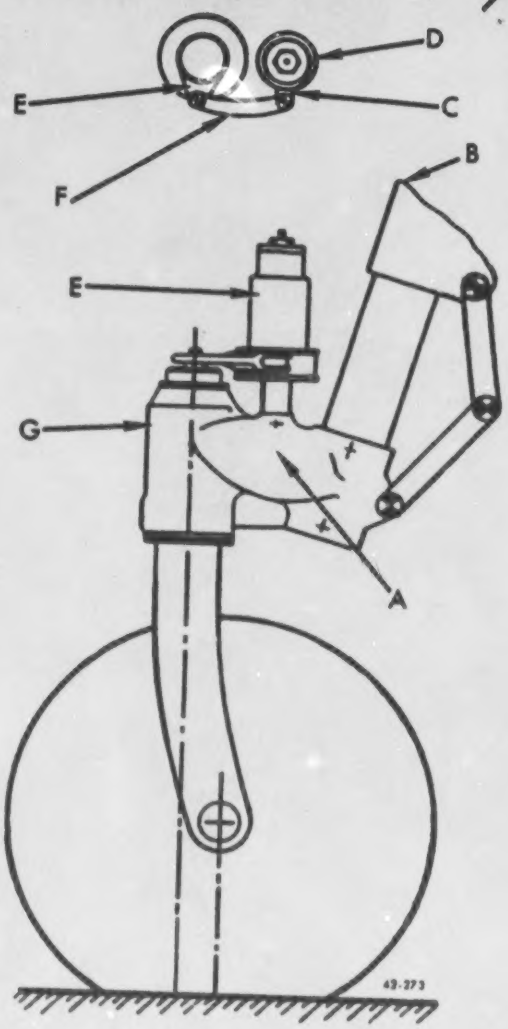
19-7. The methods of mounting vane-type dampers vary with the design of the nose gear. When the nose wheel has a limited degree of travel when turning, the damper may be mounted as in figure 89. The damper (J) is attached to a mounting bracket (E), which is stationary with respect to the strut (D). When the wheel (A) is turned in either direction, the fork (L), torque scissors (B), slipring (C & F), lever and connecting links (H and G), and the wingshaft (K) all rotate or turn. When the wingshaft rotates, the shimmy damper operates as described earlier in this section.



A. Wheel
B. Torque scissors
C. Slipring
D. Strut
E. Mounting bracket
F. Slipring
G. Connecting links
H. Lever
J. Shimmy damper
K. Wingshaft
L. Wheel fork

Figure 89. Outboard mounting of shimmy damper (limited swivel).

19-8. Outboard mounting of a vane-type shimmy damper for a full swivel wheel is shown in figure 90. The wheel spindle housing (G) is either fore or aft of the shock strut (B). On this installation the entire damper housing (D) rotates. The wingshaft of the damper is held stationary because it is attached to horizontal arm (A). This arm is also stationary with respret to the wheel assembly, which swivels. As the wheel turns, the wheel spindle inside the wheel spindle housing (G) also turns. This causes the actuating arm (E), connecting link (F), and lever (C) and the damper housing to rotate around the stationary wingshaft. This vane-type shimmy damper operates on the same principle as the dampers we discussed before.



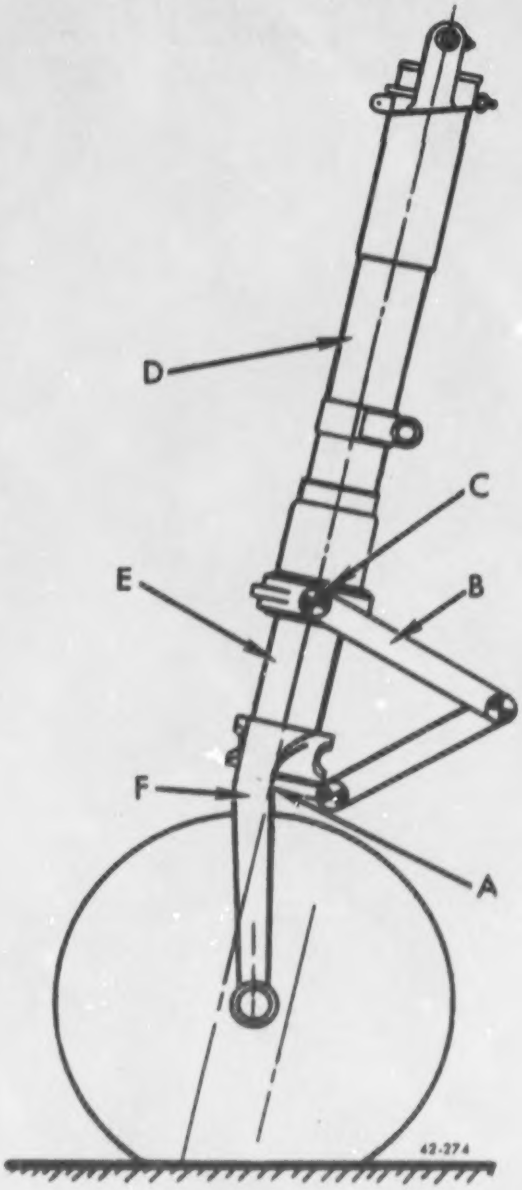
A. Horizontal arm
B. Shock strut
C. Lever
D. Shimmy damper
E. Actuating arm
F. Connecting link
G. Spindle housing

Figure 90. Outboard mounting of shimmy damper (full swivel).

19-9. Internal integral mounting of a shimmy damper is shown in figure 91. The piston tube (E) replaces the outer housing of the shimmy damper. Since the piston tube of the strut in this assembly acts as the damper housing, it rotates while the wingshaft remains stationary. This is possible because the wingshaft is attached to the strut cylinder (D) by the damper lever (A), torque scissors (B), and the pivot lug (C). Turning movement of the strut piston tube, to which the wheel fork (F) is attached, rotates the case of the damper. Thus the "stationary" vanes swing with the rotation of the piston tube. The "movable" vanes do not swing because they are fixed to the non-rotating shock strut.

19-10. **Piston-Type Shimmy Dampers.** Generally piston-type shimmy dampers are divided into two groups. There is a single-cylinder balanced type used as a single unit with the nose gear. The other consists of two piston-type shimmy dampers, each opposing the other.

19-11. The balanced type (see fig. 92) works on the principle of equal forces acting on either side of a piston. Both sides of the piston have equal areas because the piston rod runs through the piston. The unit is not part of the main hydraulic system, instead, it has it own reservoir (B). The damper is stationary with respect to the upper cylinder of the nose strut assembly; but the left end of the piston and rod assembly (D) is connected to the rotating part. It is connected, through linkage, to the section of the landing gear strut that turns with the wheel. When the wheel turns in either direction, the piston and rod assembly (D) also moves. Notice in figure 92 that passageways connect the reservoir (B) to the chambers on both sides of the piston. Each passageway has an orifice check valve (A and C). They are placed so that free flow of fluid is always toward the cylinder chambers; restricted flow of fluid is from the cylinder chambers to the reservoir. Therefore, when the piston moves to the left, fluid flows freely from the reservoir to the right hand chamber. At the same time, fluid in the left chamber must return to the reservoir through the orifice at C. When the piston moves to the right, an opposite free and restricted flow takes effect. Rapid movement of the piston caused by wheel shimmy is retarded because the fluid must flow through one of the orifices. You might be wondering why we install orifice check valves instead of just an orifice at A and C. It is to provide free flow into the cylinder, but restricted flow out. This arrangement prevents a partial vacuum from forming when the piston is moved rapidly to the right or left. If the partial vacuum is allowed to form, a spongy shimmy action will result.

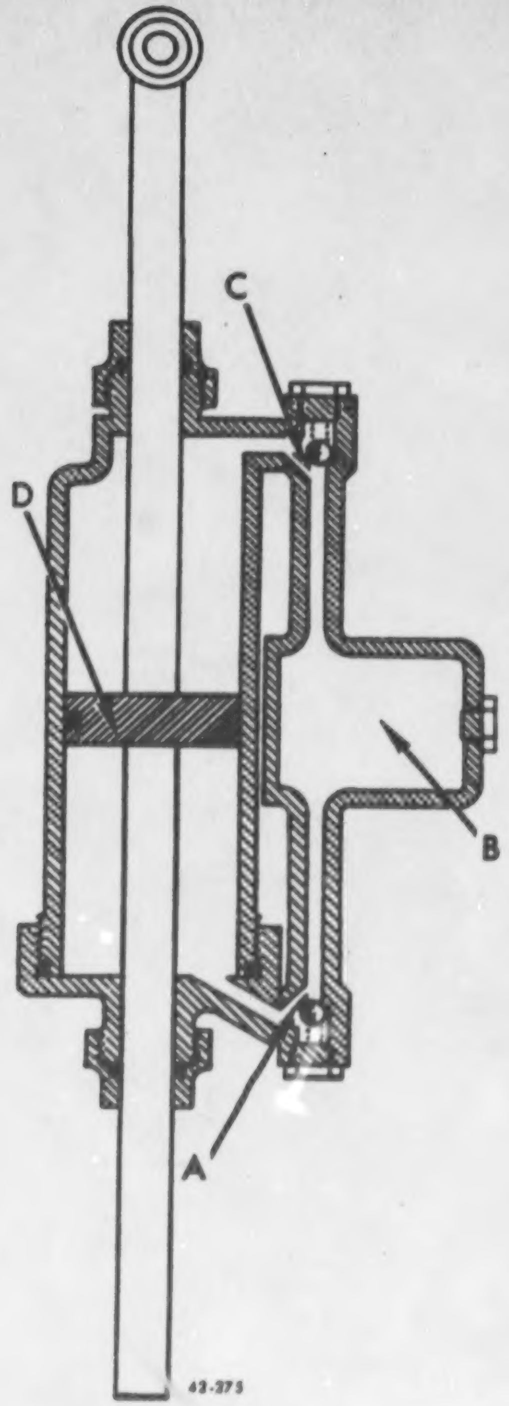


A. Damper lever
B. Torque scissors
C. Pivot lug
D. Shock strut
E. Piston tube
F. Wheel fork

Figure 91. Internal integral mounting of shimmy damper.

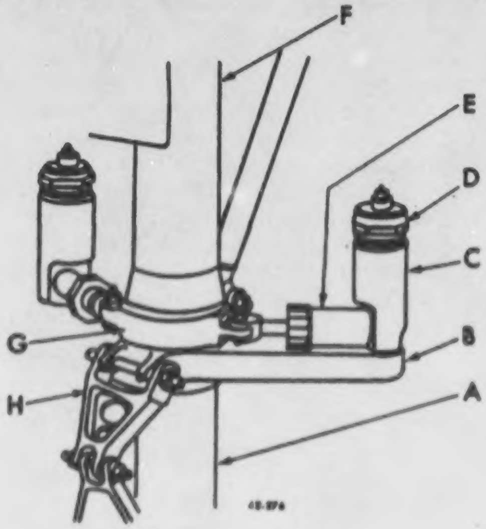
19-12. This unit is serviced with hydraulic fluid through a reservoir filler cap.

19-13. Another type of piston shimmy damper requires the use of two separate opposing units. They are mounted on a single support which pivots around the lower end of the shock



A. Orifice check valve
B. Reservoir
C. Orifice check valve
D. Piston and rod assembly

Figure 92. Balanced piston-type shimmy damper.



A. Strut piston
B. Support member
C. Spring loaded reservoir
D. Cap and spring assembly
E. Cylinder and piston assembly
F. Stationary portion of strut assembly
G. Slipring
H. Torque arms

Figure 93. Mounting of dual piston-type shimmy

strut cylinder (see fig. 93). The support member (B) rotates with the wheel fork and strut piston (A) because the two are joined by the torque arms (H). The pistons of both dampers are attached to the stationary strut assembly (F) by means of a slipring (G). Therefore, when the wheel turns in either direction the pistons of both damper cylinders are either extending or retracting.

19-14. Each damper unit consists primarily of a cylinder and piston assembly (E), an orifice check valve, and a spring-loaded reservoir assembly (C). The orifice check valves are installed between each damper assembly and reservoir. They perform the same function that the orifice check valve performs in the balanced-type damper. Fluid flow is restricted when it is being forced out of the cylinder; it is unrestricted when it is being "pulled" into the cylinder assembly.

19-15. Servicing the damper is done by removing the cap and spring assembly (D) and filling the reservoir with hydraulic fluid. Before you remove the cap and spring assembly, consult the applicable TO.

19-16. **Co-Rotating Wheels.** Another device which helps to prevent nose wheel shimmy is the use of dual co-rotating wheels. These wheels are splined to a common axle in the same fashion as train wheels. During taxiing, if the nose wheels tend to shimmy, one of the wheels attempts to rotate more than the other. It is possible that one wheel can physically move ahead of the other wheel; however, if this does happen, one or both wheels must slip or skid. Thus, you can see the co-rotating wheels offer considerable resistance to nose wheel shimmy.

19-17. The question has probably arisen in your mind, "If co-rotating wheels tend to prevent one wheel from moving ahead of the other wheel, then how can steering occur without sliding one of the wheels?" Sliding of one or both of the wheels is exactly what happens. The TOs for aircraft using co-rotating wheels will probably state that above normal wear occurs on the tires. Of course, the decision to use co-rotating wheels is made by the design engineers. Some engineers believe that doing away with shimmy dampers more than compensates for the tire wear.

19-18. Regardless of the type of shimmy damper used, some type of steering device must also be used. The age of gunning an engine for turning is fast passing by. Aircraft with co-rotating nose wheels will use only a steering unit. Those using single nose wheels will probably use a combination shimmy damper and steering unit.

20. Steering Damper Units

20-1. Nose wheel steering provides ease of handling and greater directional control during taxiing, takeoff, and landing. There are three basic types of nose wheel steering damper units presently in use. They are the dual-piston, the single-piston, and the vane-types.

20-2. **Dual-Piston-Type Steering Damper.** Figure 94 shows a dual-piston-type steering damper. With this type system, the nose wheel is steered by a control wheel located in the pilot's compartment. This system, like most nose steering systems, has an oleo-actuated shutoff valve (B) installed in the pressure line. Its purpose is to prevent any steering action *after* the aircraft is airborne. A self-centering device for the wheels is also installed to insure that the gear is streamlined for retraction.

20-3. This particular system is simple in construction, yet very satisfactory in operation. When the pilot turns the steering wheel (C), control cable linkage moves a bevel gear in a differential unit. (The differential unit will be discussed in the next volume under systems.) The movement of the bevel gear is transmitted through linkages to the metering valve (A). It opens this valve and directs hydraulic fluid under pressure to the steering actuators (F). These turn the nose wheels (E) in the desired direction. As the wheels turn, the motion is transmitted through cables back to the followup gear in the differential unit. This action returns the metering valve (A) to the neutral position. This cuts off the flow of fluid to the steering actuator, leaving the wheels turned in the desired direction. To return the wheels back to neutral the steering wheel must be turned in the direction opposite to the first turn. For simplicity we have shown the metering valve as a rotary valve; however, it will probably be a slide or spool type. This type has lands and grooves for controlling the direction of fluid flow.

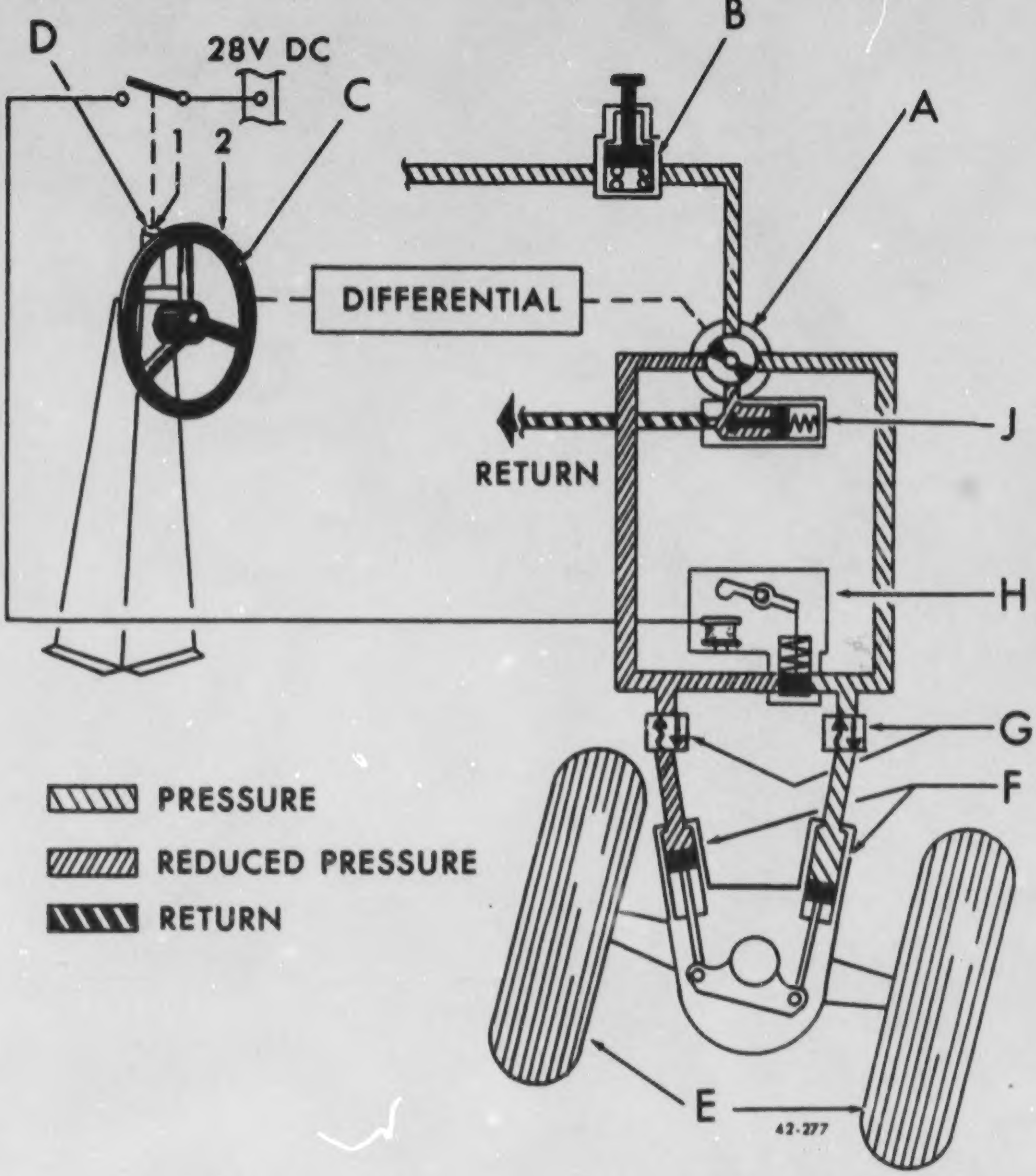
20-4. Orifice check valves (G) are installed in each line connected to the turning actuators. These valves allow free flow of fluid to the actuator and restricted flow from the actuator. This action gives a smooth, even turning of the wheels when they are steered. When the wheels are not being steered, the valves provide shimmy damper action.

20-5. A compensator valve (J) is located in the system return line. It maintains a small pressure in the steering actuators when the metering valve is in neutral. Such a pressure prevents partial vacuum in a steering actuating cylinder if the nose wheel is suddenly turned by outside forces. The compensator valve consists of a small spring-loaded piston with a built-in relief valve set at about 75 psi. Besides keeping pressure within the steering actuators, the compensator valve prevents excessive pressure due to thermal expansion.

20-6. The solenoid-operated shutoff valve (H), when open, provides a path for free flow of fluid between the two steering actuators. During aircraft towing operations we want the nose wheels to swivel freely. At such times, or if some part of the steering system fails, this valve is opened. On this particular installation, the valve is controlled by a bypass control switch (D), located on the steering column. On other installations, this valve may be opened and closed manually.

20-7. Some installations use only a single piston for steering the aircraft. A complete steering system using a single piston will be discussed in Volume 3.

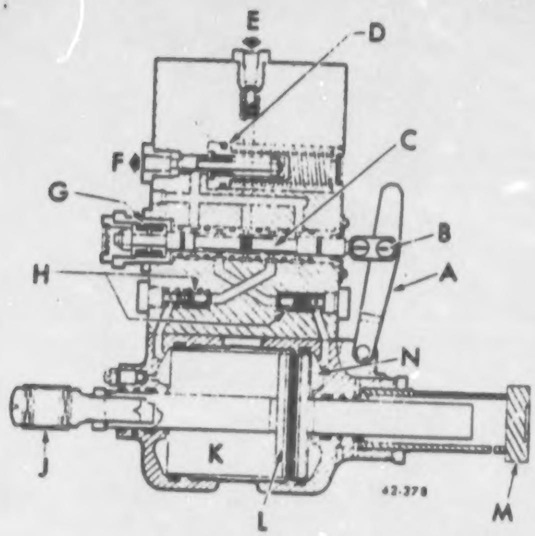
20-8. **Single-Piston-Type Steering Unit.** Figure 95 shows a single-piston-type steering unit. This unit is typical of most single-piston steering units; therefore, we shall discuss its operation in detail.



A. Metering valve
B. Oleo-actuated shutoff valve
C. Steering wheel
D. Bypass control switch
E. Nose wheels
F. Steering actuators
G. Orifice check valves
H. Solenoid-operated shutoff valve
J. Compensator valve

Figure 94. Dual piston-type steering damper system.

20-9. Steering control of this type steering-damper unit is obtained by using a spool-type control valve (C). The spool is positioned by a mechanical control lever and followup linkage (A and B). When the control lever (A) is moved, the control valve (C) is positioned to block off and open alternating ports. Notice that three ports are located on the top of the control valve (C) cylinder. The two ports at the bottom of the cylinder connect to either side of the power piston (L). Fluid from these two passageways must first pass through damping or orifice check valves (H). Again, they provide free flow toward the power piston



A. Control lever
B. Control arm linkage
C. Control valve
D. Return accumulator (compensator valve)
E. Pressure inlet
F. Return outlet
G. Centering spring
H. Orifice check valve
J. Fixed attachment point
K. Left-hand cylinder chamber
L. Power piston
M. Nose wheel attachment point
N. Right-hand cylinder chamber

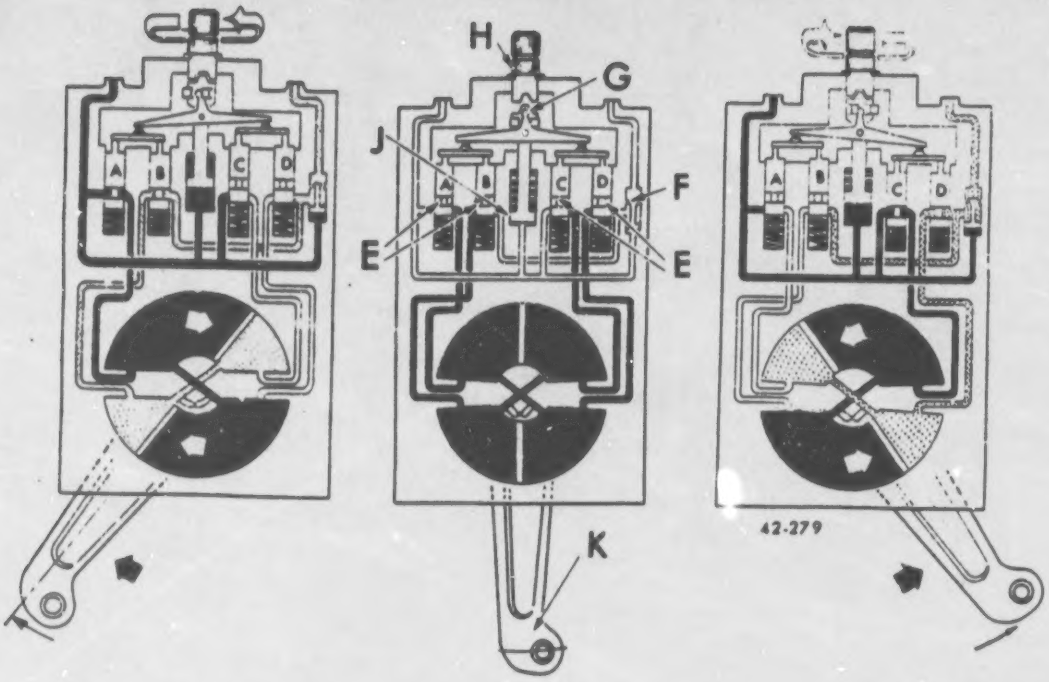
Figure 95. Single piston-type steering damper unit.

cylinder and restricted flow out. The two outer ports at the top of the control valve cylinder are connected to the return outlet (F); the center port is connected to the pressure inlet (E). A centering spring (G) holds the control valve in the neutral position whenever the steering is not being used. In the neutral position the entire assembly operates as a shimmy damper. The two orifice check valves provide the snubbing action.

20-10. The piston (L) and piston rod are fastened to the stationary part of the strut at fixed attachment point (J). The entire housing assembly is fastened to the nose wheel assembly at nose wheel attachment point (M).

20-11. For steering, the control valve (C) is moved to either the right or left by the control lever (A). If the valve moves to the right, the center pressure port is opened, sending fluid to the bottom left-hand port. From there it goes through the right orifice check valve and on to the right-hand cylinder chamber (N). The upper left-hand return port of the control valve, is blocked off, but the upper right-hand return port is opened. This allows fluid from the left-hand cylinder chamber (K) to return through the orifice to the left-hand orifice check valve and on to the reservoir. As fluid pressure enters the right-hand cylinder chamber (N), the entire housing moves to the right, thereby turning the nose wheel. NOTE: The upper end of the control lever (A) does *not* move to the right. As the housing moves to the right, it catches up with the initial right-hand movement of the control valve. This places the control valve back into its neutral position. As long as the control valve is kept ahead of the movement of the housing, the nose gear will keep turning. That is, until it reaches its maximum turn. The return accumulator (compensator valve) (D) serves the same purpose as the compensator valve in the dual-piston-type steering system discussed before.

20-12. **Vane-Type Steering Damper Unit.** This unit, shown in figure 96, serves two functions. It acts as a steering device and as a shimmy damper. When the unit is not being used for steering, it acts as an ordinary shimmy damper. As a shimmy damper, it works like the vane-type shimmy damper described in a previous paragraph. For nose wheel steering, it uses fluid pressure from the normal hydraulic system. There are four control poppets (E) in the control mechanism. They are pressure and return poppets A and B for right-hand turns and pressure and return C and D for left-hand turns. The middle view in figure 96 shows the neutral position. In this position all ports from the poppets to the damper mechanism are blocked off. During the steering operation, pressure enters the unit through the upper left port. (Under systems in the next volume you will learn what sends this pressure.) It is routed to the right-turn pressure poppet (A), to the left-turn pressure poppet (C). It is also routed to the steering engaging valve (J) and to the fluid return valve (F). Pressure forces the steering engaging valve up. This causes steering control rocker arm and cam (G) to rise and engage the control shaft (H). A steering lever operated by the pilot rotates the control shaft in either direction. For right turns (fig. 96, left view), the control shaft and cam arrangement cause the rocker arm to force the right -turn poppet valves (A and B) down. This allows pressure to pass through pressure poppet A to the right-turn chambers of the damper assembly. Also, fluid from the opposite chambers can pass through return poppet B back to the return line. The initial application of pressure to the unit opened up the return valve (F). Opening this valve allows unrestricted flow of return fluid. The steering arm (K) is attached to the nose wheel and causes the wheel to turn



A. Right-turn pressure poppet
B. Right-turn return poppet
C. Left-turn pressure poppet
D. Left-turn return poppet
E. Control poppets

F. Return valve
G. Rocker arm and cam
H. Control shaft
J. Steering engaging valve
K. Steering arm

Figure 96. Operation of vane-type steering damper unit.

to the right. If the control shaft is rotated for left turns, the left-turn pressure and return poppets (C and D) are pushed down. This opens up the pressure and return lines to the opposite chambers of the damper. Now it will turn the steering arm and nose wheel to the left (fig. 96, right view). A followup system must be added to make it easier to steer the aircraft. It keeps the nose wheel from going all the way to the right or left when the steering is actuated. Too, it matches the movement of steering arm (K) to the degree of turn the pilot feeds into the system. How this is done will be explained in the next volume when you study the complete system. Study the center view; it will help you to figure out the shimmy damper operation.

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Brake System Components

IN THIS CHAPTER we will discuss the uses of brake systems. You will learn how these systems can be arranged in many different ways; specific designing depends upon such factors as the landing gear layout and size and type of the aircraft. We will cover the operation of several typical systems; and, we will thoroughly cover the operation of the individual units. You will also, be given a chance to troubleshoot a few typical situations.

2. Braking systems are needed on a wide range of vehicles. Automobile, truck, and bus brakes are designed to provide equal braking action at all wheels and straight-line stops. A mechanical parking device, able to hold the vehicle on hills, is usually built into the system.

3. Aircraft brake systems are somewhat different from each other because the must meet different requirements, but they are used to stop the aircraft after landing and during taxiing. On many aircraft, brakes are used to steer the aircraft during ground operation. A provision for parking the aircraft is also built into the brake hydraulic system. Trapped hydraulic pressure is used to hold the brake assemblies in the applied position for parking.

21. Introduction to Brake Systems

21-1. Even though landing gear arrangements vary, all aircraft brake systems fall into three main types: independent, integral, and slave brake systems.

21-2. **The Independent Brake Systems.** The independent brake system is not connected to the aircraft's main hydraulic system in any way. Hydraulic braking pressure is developed entirely by foot force on the brake pedal. This force is transmitted through mechanical linkage to a master cylinder, which converts the mechanical energy into hydraulic pressure for brake application.

21-3. **Integral Brake Systems.** Integral brake systems obtain braking pressure from the main hydraulic system. Some systems meter main system fluid directly to the brake through a pedal-operated power brake valve. *Other* integral systems are of the hydraulic *boost* type. They use metered pressure from the main hydraulic system to act upon one side of a piston. On the other side of the piston is the fluid that goes to the brakes. As the brake pedal is applied, it meters main system pressure to its own side of the piston. Thus, the brake is applied by foot-power plus main system pressure applied to the piston. The piston, in turn, applies pressure to the fluid in the brake line. The boost system does not send main system fluid to the brake assemblies. The normal integral brake system does.

21-4. **The Slave Brake Systems.** The slave brake system is a combination of the independent and integral systems. Used on some very large aircraft, it consists of a slave meterring valve remotely controlled by a master cylinder through a long pressure tube. Brake pedal action causes the master cylinder to pressurize fluid that is directed to the slave metering valve. The slave metering valve then meters main system fluid to the brake assembly.

21-5. Slave brake systems on large aircraft are safer and lighter than simple power braking systems. True, the master cylinders add weight. But, the lines carrying master cylinder pressure to the slave metering valve are relatively small. Therefore, these lines are much lighter than those carrying pressure from a single metering valve system. On very large aircraft, the length of tubing required to carry fluid from the cockpit to the brake assemblies is considerable. So, the use of small tubing represents a definite weight reduction. Since the slave metering valves are remotely controlled, they can be close to the brake assemblies. Thus, the lines carrying system high pressure are short and do not enter the cockpit. (The absence of large high-pressure lines from the pilot's compartment decreases the fire hazard.)

21-6. **Thermal Expansion in Brake Systems.** All hydraulic brake systems must have means of relieving the expansion of fluid caused by heat. This thermal expansion can occur in both the ON and OFF positions of the brakes. Thus, brake systems must be built to allow room for this expansion of the fluid at all times.

21-7. When brakes are in the OFF position, thermal expansion must be bled off to the reservoir. If the expanding fluid has no outlet, it will pressurize the brake system and apply the brakes.

21-8. Likewise, thermal expansion can occur when the aircraft is parked and the parking brakes are on. This excess pressure must be relieved lest it break a line or blow a seal. Sometimes it is relieved by a thermal relief valve set higher than normal braking pressure. In other systems, this extreme pressure may be limited by a feature built into the master cylinder or metering valve.

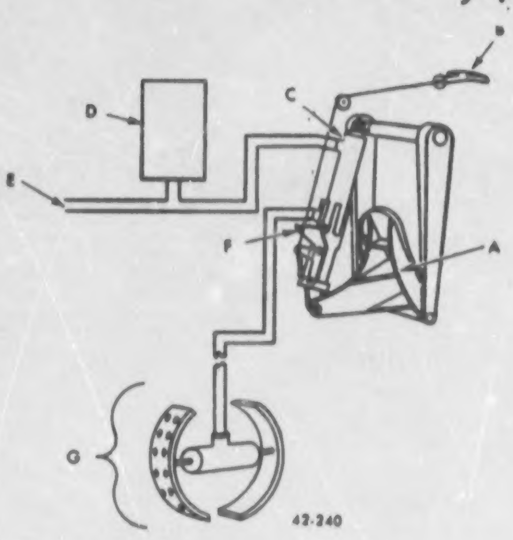
21-9. In addition to providing for thermal expansion, brake systems must have another feature. They must also be able to replace the small amount of fluid which may be lost through normal system leakage. This is done when the brakes are off. The same passage which relieves the increase in volume due to thermal expansion generally serves to allow fluid to enter the braking system.

22. Independent Systems

22-1. An independent brake system is illustrated in figure 97. This system is generally found on fighter-type and liaison-type aircraft. Usually, the independent system is not connected to the main hydraulic system of the aircraft, except in some cases where the brake systems are supplied with reserve fluid from the main system. Hydraulic braking pressure is developed entirely by foot pressure on the brake pedal. The hydraulic units of an independent system (fig. 97) consists primarily of a reservoir (D), a master cylinder (C), and a brake unit (G).

22-2. **Reservoirs.** Some systems have one reservoir that supplies fluid to both the right and left master cylinders. In other systems, each master cylinder has its own individual reservoir. These reservoirs contain a reserve supply of fluid to replenish that which is lost through normal leakage. They also have space to hold any excess volume that may result from thermal expansion.

22-3. **Master Cylinders.** There are many types of master cylinders, and they vary in size and shape, depending on their use. Because of their *low volume output*, they are mostly used with small brake assemblies installed in lighter aircraft. All properly functioning master cylinders produce the same result; they develop hydraulic braking pressure. They are connected to the brake pedal by mechanical linkage. Depressing a brake pedal causes the master cylinder piston to move, sending fluid to the brake assembly to apply the brake.

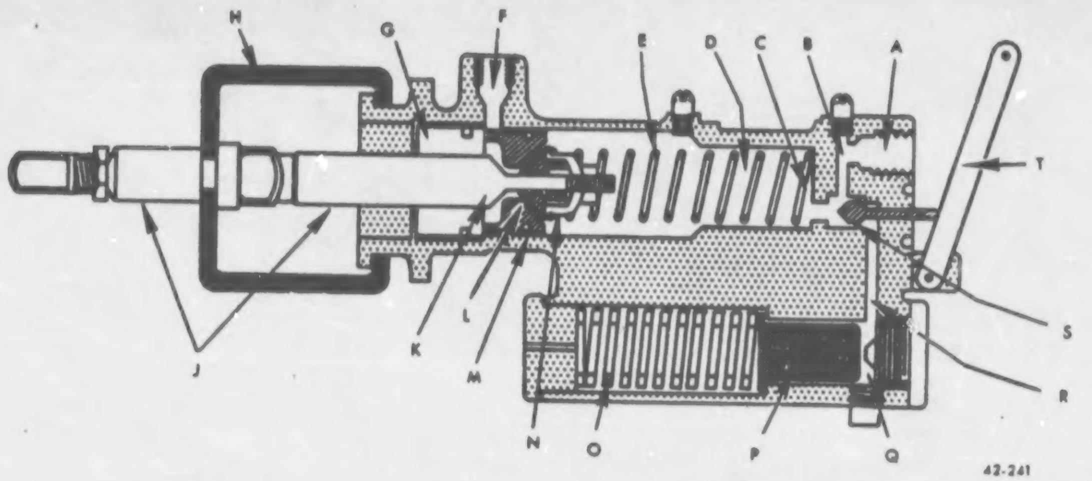


A. Brake pedal
B. Parking T-handle
C. Master cylinder
D. Brake fluid reservoir.
E. Fluid supply line to other master cylinder
F. Parking ratchet
G. Brake assembly

Figure 97. Independent brake system.

22-4. The mechanism can also be used as a parking brake. With the system shown in figure 97, an aircraft may be parked by first depressing the brake pedal (A). This action causes the master cylinder (C) to send fluid to the brake assembly. When full braking pressure has been attained, the parking T—handle (B) is pulled. This engages the parking ratchet (F), which holds the master cylinder in the brake applied position. The other line (E) from the reservoir is connected to the master cylinder for the other brake assembly. The operation of both the right and left brake is identical. The brakes may be released from the parked position by firmly depressing the pedals. This action releases the ratchet and allows the master cylinder to return to the OFF position.

22-5. **The Gladden Master Cylinder.** This master cylinder is typical of the ones used on several of our fighter and liaison aircraft. It, like all others, converts mechanical force into



A. Brake port
B. Passageway
C. Passageway
D. Master cylinder chamber
E. Return spring
F. Reservoir port
G. Bushing
H. Protective boot
J. Piston rod
K. Poppet
L. Piston head passage
M. Small spring and retainer
N. Piston head
O. Compensating spring
P. Compensating piston
Q. Compensating chamber
R. Compensating passage
S. Compensating poppet
T. Lever

Figure 98. Cross section of a Gladden master cylinder.

hydraulic pressure. Figure 98 illustrates the Gladden master cylinder. The pilot's brake pedal is mechanically linked to the master cylinder piston rod (J). Whenever the brake pedal is pushed down, the piston rod moves to the right. The first movement of the rod will push the retainer of the small spring and retainer (N) away from the piston head M. This allows the poppet (K) to seat or piston head (M) before the piston head move . The reason for this action is to seal piston head passage (L) before the piston head moves. This traps the fluid in the master cylinder chamber (D) when the piston head moves forward.

22-6. Now, as the piston rod continues to move to the right, it pressurizes the fluid in chamber D. The fluid is forced out into the brake lines through passageways C and B and the brake port (A). To help you better visualize these movements of parts and fluid, also refer to figure 99. The wheel brake assemblies are thereby actuated, and the friction surfaces are brought into contact. The braking force applied on the contact surfaces is in direct proportion to the force applied on the brake pedal.

22-7. Braking stops when foot force on the pedal is released. Refer to figure 98. This allows the return spring (E) to force the rod and piston back to the left. Slotted fingers extend rearward from the piston head and contact the bushing (G). This action stops the leftward movement of the piston head. The piston rod will continue to move to the left until the retainer part of N is again seated on the piston head. This extra movement again lifts poppet K from its seat on the piston head and reopens the piston head passage (L). Now, if any fluid was lost by leakage during application of the brake, it can be replaced. Fluid will be drawn from the reservoir through the reservoir port (F), into the chamber behind the piston head. From there it will pass through the piston head passage to fill the void in chamber D. This route also permits return flow of fluid from the system to the reservoir if thermal expansion occurs. That is, when the brakes are not applied.

22-8. When parking an aircraft equipped with Gladden master cylinders, first depress the brake pedals to pressurize the brake systems. Next, pull the parking T-handle. As this is done, the action in each of the cylinders proceeds in the following manner: The lever (T), which is cabled to the T-handle, moves to the left. This movement forces poppet S to close passageway C. This, the fluid is trapped under pressure in the brake line and assembly. The brake pedals can then be released. The piston head (N) and piston rod (J) will return to the BRAKE OFF position. However, the brake will remain in the applied position because the fluid in the system is trapped under pressure. In addition, this fluid pressure holds poppet S firmly on seat. Actually, then, the parking handle could be returned to the normal position without losing parking pressure. This is because trapped pressure holds poppet S on seat. However, the T-handle should be left in the parked position as an added safety precaution.

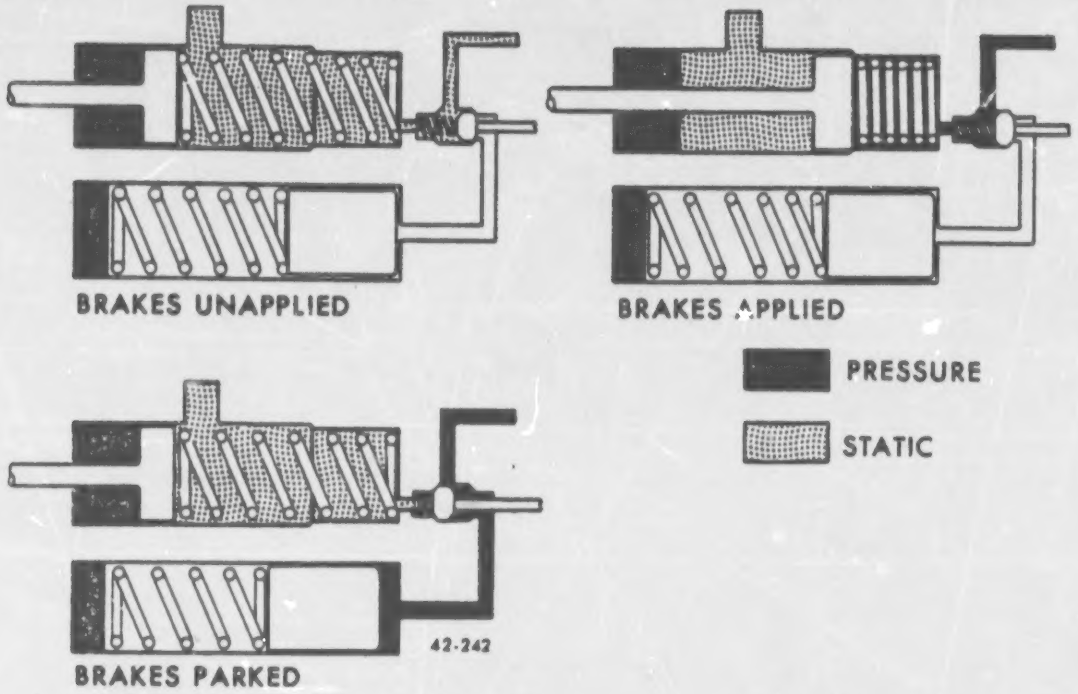
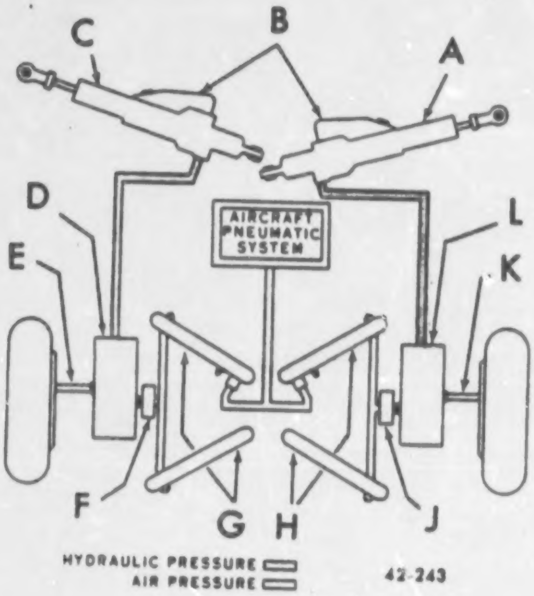


Figure 99. Schematic flow diagram of master cylinder.

22-9. To release the brakes after the aircraft has been parked, return the T–handle to its normal IN position. Then firmly depress the brake pedals. This pressurizes each master cylinder chamber to where it overcomes brakeline pressure. As a result poppet S is forced off its seat. Release of the pedal will then move the piston head (N) to the left. Now fluid from the brake assembly can reenter the cylinder chamber through the open passageway C.

22-10. The compensating chamber (Q) and piston (P) make up for thermal expansion and fluid replenishment while the aircraft is parked. When the brakes are applied and the T–handle is pulled, the compensating poppet (S) is repositioned. It moves from its seat blocking the compensating passage (R) to a seat blocking passageway C. As it moves across, it will momentarily leave both seats uncovered. At that moment fluid pressure can enter the compensating chamber (Q) through passage R. It will push the compensating piston (P) to the left, compressing the compensating spring (O). Thus, when the aircraft is parked, there is fluid trapped in this chamber. This chamber, spring, and piston acts like a spring-loaded accumulator. It stores fluid under pressure to handle any decrease in brake pressure, due to leakage or thermal contraction. Likewise, if thermal expansion takes place in the brake assembly, it will absorb the added volume. Thus, the compensating spring and piston maintain a balance in the brake system under varying temperatures.

22-11. **Pneumatic Brake System—Master Cylinder Operated.** Some aircraft use a master cylinder brake system that is different from the one just discussed. They use a hydraulic master cylinder that does not direct fluid to the brake unit. It directs fluid only to an air relay valve (metering valve), which in turn directs compressed air to the brake unit for braking action. Figure 100 shows the brake system. The master cylinders (A and C) are similar in operation to the ones we have already discussed. The main difference is that each cylinder has its own reservoir mounted directly on it. When you depress the left brake pedal, the left master cylinder (C) forces hydraulic fluid through the brake lines to the air relay valve (D). This hydraulic pressure is applied to a metering piston in the relay valve. Movement of the piston causes compressed air to be directed through the air line (E) to the brake unit. The air pressure metered through the relay is in proportion to the hydraulic pressure applied to the piston. When the brake pedals are released, the relay metering piston goes back to the neutral position. When in neutral, the relay valve piston opens a passage which vents the brake air pressure line (E) overboard.

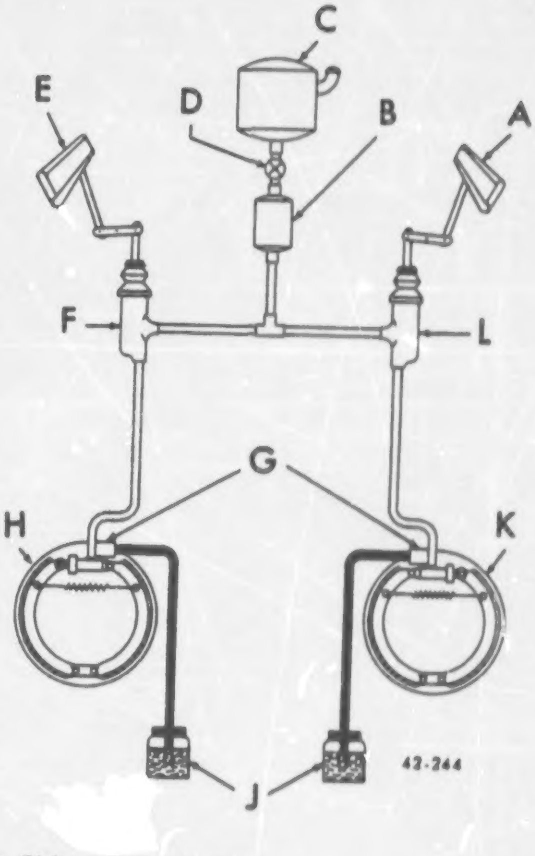


A. Right master cylinder
B. Reservoir section of master cylinder
C. Left master cylinder
D. Relay valve
E. Air line to brake unit
F. Air filter
G. Left drag brace accumulators
H. Right drag brace accumulators
J. Air filter
K. Air line to brake unit
L. Relay valve

Figure 100. Master cylinder brake system.

22-12. Air pressure for the brake systems is stored in the hollow main landing gear's drag brace struts. These struts are shown as items G and H in figure 100. As part of the landing gear assembly, they brace the oleo strut. These hollow storage spaces acts as air accumulators. Each storage area is provided with high-pressure relief valves and bleed plugs. Air pressure in the drag brace accumulators is supplied by the aircraft's high-pressure pneumatic system. The high-pressure air enters the drag braces through check valves to insure enough compressed air for one safe landing should the pneumatic system fail.

22-13. The previous paragraphs explain how master cylinders can be used in different kinds of brake systems. Regardless of the type of system it is used in, the operation is basically the same. In Volume 3, you will see how this system is connected to the entire aircraft pneumatic system.



A. Right rudder brake pedal
B. Brake reservoir
C. Gravity feed filler tank
D. Shutoff valve
E. Left rudder brake pedal
F. Left master cylinder
G. Bleeder valves
H. Left brake assembly
J. Glass jars
K. Right brake assembly
L. Right master cylinder

Figure 101. Brake bleeding with gravity tank.

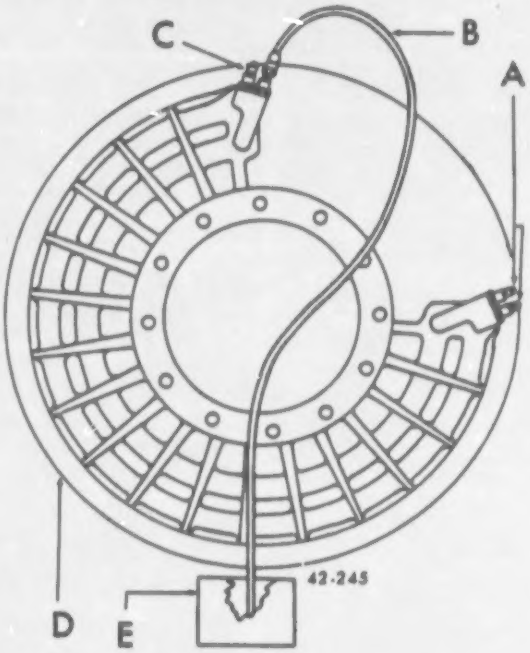
22-14. **Bleeding Independent Brake Systems.** Any time air gets into a hydraulic brake system, the brakes must be "bled." (Bleeding brake systems is the act of flushing out the air-polluted fluid with fresh, pure fluid.) Air may get into the hydraulic brake system when you replace such units as brakes, master cylinders, lines, or other items. Air may also be forced into the system by the master cylinder if the pedal is depressed while the reservoir is empty. Likewise, as the brake pedal is released, retraction of the master cylinder piston may cause a partial vacuum that could suck air into the system through any existing leaks. The formation of air pockets in the brake system causes brake pedal operation to feel "spongy." This is because the air must first be compressed before braking pressure can be developed. Braking action becomes erratic. This air must be purged from the system before operation can return to normal.

22-15. The recommended method of bleeding air from independent brake systems is called the *gravity method*. It is essential that only clean, pure, strained fluid of the proper specification be used during operation.

22-16. Where filling and bleeding is regularly done, a gravity tank should be on hand. Figure 101 shows an independent system properly connected for gravity bleeding. The tank (C) should have one or two outlets at the bottom. Each outlet has a shutoff valve with a hose fitting at its outlet. The tank should have a filler opening at the top equipped with a fine screen; also, the cap must have an air vent. It is important that the tank contain a large supply of fluid before you start bleeding the brake system.

22-17. The tank outlet hose is first connected to the brake reservoir (B) port. If each master cylinder (F and L) has its own reservoir, a tank hose is attached to each reservoir inlet port. You will find a bleeder valve (G) located near the highest portion of each brake assembly. Remove the dust cap (or screw) from the bleeder valve. Then screw a soft hose with a threaded fitting in one end into the bleeder valve. Place the loose end of the hose in a glass jar (J) partly filled with clean brake fluid. The end of the hose should be submerged in the fluid. When the hose and jar are properly connected, open the bleeder valve. (Check your TO on how to open the bleeder valve on the brake you are bleeding.) Now the fluid can flow from top of the brake assembly through the bleeder valve into the glass jar. To begin fluid flow, open the filler tank shutoff valve (D). When the reservoir is full, begin alternately applying and releasing the brake pedal. Continue pumping the brake pedal until air bubbles no longer appear in the glass jar. The amount of fluid required to bleed the system depends on the size of the system as well as the amount of air in the system. When all the air is bled from the system, close the bleeder valve and remove the bleeder hose. Then replace the dust cap on the bleeder valve. Finally, close the tank shutoff valve and remove the tank.

22-18. Some maintenance organizations may use a slightly different method for bleeding the brakes. They use the same equipment and hookup as mentioned above, but the actual brake bleeding definitely requires two men, one in the cockpit and the other at the bleeder valve. The man at the bleeder valve opens the valve while the brake pedal (A or E in fig. 101) is being depressed. Then, he closes the valve *before* the brake pedal is released. This eliminates any chance of air being sucked back into the system through the bleeder valve when the pedal is released.



A. Bleeder valves
B. Hose for bleeding
C. Bleeder valves
D. Brake assembly
E. Glass jar

Figure 102. Brake assembly with four bleeder valves.

22-19. The brake assemblies shown in figure 101 have only one bleeder valve. But often there may be more than one. Figure 102 for example, shows a brake assembly that uses four bleeder valves. In an assembly such as this, the above brake bleeding procedures must be performed at each bleeder valve. Relate the callout letters in figure 102 to the discussion of figure 101.

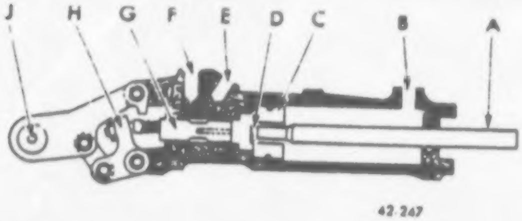
23. Integral Brake Systems

23-1. Many aircraft now have some type of power brakes or power-assisted brakes. They use hydraulic pressure from the aircraft's main hydraulic system to provide most or all of the energy required to apply the brakes. These brake systems are called *integral* because they are integrated with the main hydraulic system. Some of these booster type systems use metered system pressure to aid the pilot in pushing the master cylinder piston. Others meter the main system fluid directly to the brake assemblies. Some others use one brake valve to control another brake valve; this type of operation is called a *slave brake system.*

23-2. In all cases, thermal expansion and fluid loss must be compensated for in both applied and unapplied positions. "Load feel" is built into the brake system so that the pilot is aware of the amount of braking action taking place.

23-3. **Master Boost Cylinder.** A master boost cylinder is shown in figure 103. This unit is a master cylinder that uses aircraft hydraulic system pressure to aid the pilot apply the brakes. The boost pressure fluid does not go through the master cylinder to the brake line; it only assists the master cylinder piston in its pressure stroke.

23-4. When the brakes are applied, the piston rod (A) is pulled away from the cylinder. The cylinder is held stationary at the cylinder pivot attachment point (J). This rod movement first causes the poppet (D) to seat on the cylinder piston (C). Continued movement of the piston rod then pulls the piston to the right. This forces fluid out the cylinder port (B) to the brake assembly. As pressure begins to rise, more resistance to the pull develops. As a result, the piston rod (A) and pivot attachment (J) tend to form a straight line. This causes the lever arm (H) to push the sliding spool (G) to the right. As the spool moves to the right, the return port (F) closes and the pressure port (E) opens. System pressure now enters the narrow space of the spool and flows through the drilled passage in the spool. This pressure will cause the area between the spool (G) and piston (C) to become pressurized. Such pressure gives the boost action that aids the pilot in applying the brakes. Boost pressure also acts on the right end area of the spool (G). This causes it to move back against its spring until the narrow part is between the pressure and return ports. This cuts off all fluid flow through these ports. If the pilot wants to increase brake pressure, he pushes a little harder. This offsets the spool (G) again long enough for boost pressure to increase proportionally. Maximum brake pressure is manually adjusted by turning a nut located on the lever arm (H).



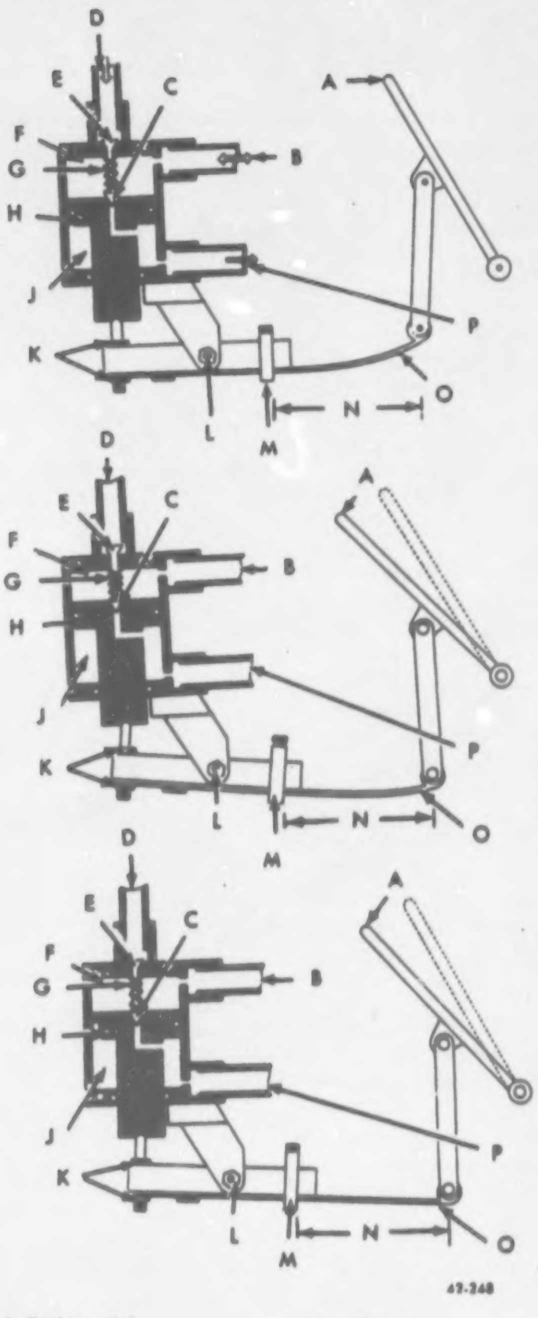
A. Piston rod
B. Cylinder brake port
C. Cylinder piston
D. Poppet
E. Pressure inlet port
F. Return port
G. Sliding spool
H. Lever arm
J. Pivot attachment

Figure 103. Master boost cylinder.

23-5. **Power Brake Control Valve.** The power brake control valve (PBCV) is the heart of the brake metering valve controlled system. This type system is usually found on bombers and cargo aircraft. A power brake system is quite simple. It consists of a PBCV with hydraulic lines connecting it to the main system pressure and return, and to the brake assemblies. Linkage connecting the PBCV to the brake pedals is much like the linkage on other types of brake systems. Parking the aircraft is generally done by holding the brake control valves in the ON position by means of a mechanical locking mechanism in the pedal linkage. To explain operating principles of brake control valves, consider the single Bendix PBCV. It is shown in figure 104. Although this valve is no longer in common use, it is given as a representative sample to explain operating principles. It is a good valve for this purpose. Smaller, more complex dual units will be easier to understand if you are clear on this one.

23-6. In the top illustration, the valve is shown in the unapplied position. Note that lower poppet (C) is not seated on the piston. Thus, there is an open passage between the reservoir return port (P) and the brake pressure line port (B). This provides a path for fluid replenishment and thermal expansion when the brakes are in the OFF position. Also, notice that the top picture shows the pressure port being blocked by the upper (pressure) poppet (E).

23-7. The valve begins metering fluid when the brake pedal (A) is depressed. This causes the right-hand end of the leaf spring (O) to move downward. Because the spring block pivots, the left-hand end moves upward, forcing the piston (H) against the lower poppet (C). As piston movement continues, the upper poppet (E) is unseated (middle illustration, fig. 104). This allows fluid to enter the upper chamber (F) to the valve and flow out the brake line port (B) to the brake. As pressure increases in the brake, it also builds up in the upper chamber of the break valve. This increasing pressure creates a downward force on the piston. Since the brake pedal remains depressed, the piston will move downward when fluid force overcomes the strength of the leaf spring (O). Fluid pressure and the small spring (G) cause the lower poppet to remain seated and follow



A. Brake pedal
B. Port to brake assembly
C. Lower (return) poppet
D. Pressure inlet port
E. Upper (pressure) poppet
F. Upper chamber
G. Small spring
H. Piston
J. Lower chamber
K. Low-pressure adjustment nuts
L. Pivots
M. Yoke (high pressure) adjustment
N. Effective leaf spring length
O. Leaf spring
P. Return port to reservoir

Figure 104. Schematic of Bendix PBCV.

piston movement. As the movement continues, the upper poppet (E) seats again. This traps the fluid under pressure in the brake assembly, maintaining braking action. This position of the valve is shown in the lower illustration of figure 104. Downward force on the piston is transmitted through the linkage to the brake pedal. This force provides the pilot's foot with an opposing force that is proportional to the amount of braking pressure. Thus, the pilot has "load feel."

23-8. When the aircraft is parked, a constant force is exerted on the brake pedal. During such a period, fluid may be lost from the brake line or assembly. Such a loss will cause a pressure drop in the upper chamber of the PBCV. The leaf spring then will overcome the decreased force on the piston, forcing it and the poppet upward. This will permit more fluid to enter the brake system through the inlet port (D). This action again raises the pressure to the original level.

23-9. What happens if thermal expansion occurs while the aircraft is parked? The enlarged fluid volume will raise the fluid pressure within the upper chamber (F). The downward force on the piston will overcome leaf spring force and move the piston downward slightly. As the piston lowers, it leaves the lower poppet, thereby opening the passage through the piston. This allows fluid to excape out through the lower chamber (J) and return port (P). Enough will escape until leaf spring force again overcomes the decreasing fluid force on the piston. At that time the piston will rise, and again trap the fluid in the brake system.

23-10. The pressure metered to the brakes depends upon the distance the piston moves upward; this distance is determined by the force applied to the brake pedal. A small amount of pedal pressure forces the piston upward a slight distance. Then, a relatively low pressure in the brake system can force the piston downward. It will be enough to bend the leaf spring the slight amount necessary to allow seating of the upper poppet.

23-11. A large amount of force on the brake pedal causes the piston to rise a considerable distance. In this case, a high brake system pressure is needed to force the piston downward the increased distance. From this it may be seen that the pressure metered to the brake assembly is controlled by the PBCV; this pressure is proportional to the applied pedal force. However, each system does have a certain designated maximum pressure. This pressure varies between aircraft models, but it is always enough to lock the wheels against rotation. Higher pressure is not wanted as it might possibly burst the brake lines or rupture the seals. Therefore, an adjustment is provided on the brake control valve to limit maximum pressure output.

23-12. The maximum pressure delivered by the Bendix PBCV is controlled by leaf spring tension. When the brake pedal is fully depressed, the piston rises a definite distance until poppet E opens. Incoming pressure in the upper chamber forces the piston back down this distance before the upper poppet again seats. To do so, the pressure must overcome the leaf spring force. If we increase the leaf spring tension, we also increase the pressure required to force the piston downward. Likewise, if we decrease leaf spring tension, less pressure will force the piston down to where poppet E closes.

23-13. The yoke adjustment(M,shown in fig. 104) controls the leaf spring tension. It does so by increasing or decreasing the effective spring length (N). When the yoke is moved away from the pivot point (L), the effective length of the spring is decreased; because only the portion of the spring that is to the right of the yoke can flex. This increases maximum metered brake pressure since a higher pressure is required to bend the shortened spring. The high-pressure adjustment is initially set by the manufacturer. In time it may require readjustment because of spring fatigue, vibration, or careless maintenance. Besides the high-pressure adjustment, there is also a low-pressure adjustment on the PBCV. The low-pressure adjustment nuts (K) regulate the piston height when the brake pedal is released. The low-pressure adjustment insures zero pressure in the brake system when brakes are unapplied. Poppet C must be open to give zero pressure. The piston height is adjusted to provide a clearance between the piston and the lower poppet. This furnishes an open path for thermal expansion and fluid replenishmen It also insures that the upper poppet is seated, preventing pressure flow into the brake system.

23-14. **Adjusting Power Brake Control Valve Systems.** If you can adjust the PBCV in figure 104, you can adjust most other brake controls and metering valves.

23-15. As previously stated, it is possible for the high- or low-pressure adjustment to change. The high-pressure adjustment can be checked with a pressure gage attached to the brake port (B). Maximum brake pedal force should meter a certain specified pressure to the brake assembly. Assume the pressure gage indicates less han the maximum braking pressure specified in the aircraft TO. To increase the pressure, the yoke must be moved further from the pivot. This shortens the effective spring length, which increases maximum braking pressure. A higher-than-specified gage reading is corrected by moving the yoke closer to the pivot. This lengthens the effective spring length, which decreases the maximum metered pressure.

23-16. The low-pressure adjustment is set b the manufacturer and should need no furthe attention. However, sometimes changes a made in the connecting linkage from the ped to the valve. Or, if the adjusting nuts (K) ha been tampered with, the low-pressure adjustment may be off. If the piston is too low, the indication is excessive "free pedal" before the braking action begins. A piston that is too high may unseat the upper poppet. This will allow a small amount of pressure to build up in the brake system and cause "dragging" brakes. To obtain correct low-pressure adjustment, apply pressure to the system port (D) with the brake port (B) open. The piston is then raised by turning nuts (K) until a small amount of fluid flows out the brake port. The adjusting nuts are then turned back a specified amount. This lowers the piston until the proper clearance is obtained between the piston and lower poppet. The TO on the PBCV gives the number of turns through which the adjusting nuts must be rotated.

23-17. **Bleeding PBCV Systems.** Bleeding of the PBCV is much like the methods used with the independent systems. The gravity method, however, is the hard way to do a comparatively simple task. A means of bleeding that is easier than the gravity method is internal pressure bleeding.

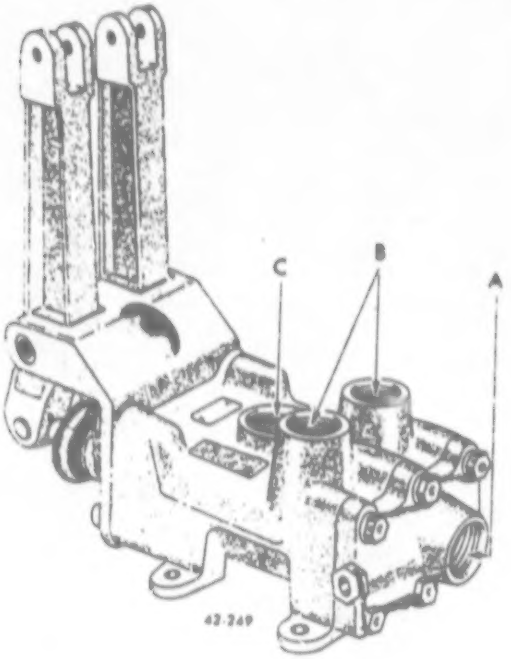
23-18. To bleed the brake system in this manner, first be certain that the main hydraulic reservoir is filled. Then, connect a hose from the wheel bleeder to a clean jar in the regular fashion. Now, build up hydraulic system pressure. Next, open the wheel bleeder approximately one turn, and depress the brake pedal. This causes the pressure poppet of the PBCV to be unseated, allowing fluid to flow to the brake. There it escapes from the assembly through the bleeder. This flow must continue until the escaping fluid is completely free of air bubbles. When all air has been purged from the system, the bleeder is closed, release the brake pedal. It is important that a nearly normal fluid level be maintained in the aircraft reservoir during bleeding.

23-19. **Dual Power Brake Control Valves.** Dual PBCV's are used on many of the larger aircraft. This valve is nothing more than two single valves built into one housing casting. There are advantages to the dual valve, as compared to the single units. The weight of the unit, as well as the number of connections, is less than two singles. A dual PBCV, such as that shown in figure 105, has only four fluid port connections. Two single valves would require a total of six hydraulic ports. Each side of the dual valve operates the same as a single valve. But, the right and left sides share a common pressure and a common return line.

23-20. In figure 105, port A on the extreme right-hand end of the valve is the pressure inlet port. The two ports B, located side by side on top of the valve, are the brake ports. The common return port (C) is located in the center of the valve directly behind the brake ports.

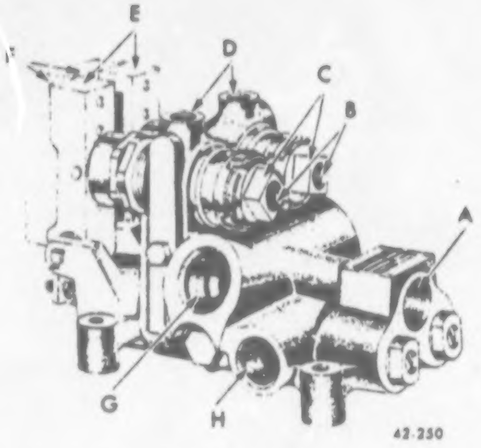
23-21. Dual PBCV's have some disadvantages. A leaking return poppet or piston seal in one of the valves or a leak in one of the brake lines or assemblies can cause the loss of pressure in both brakes.

23-22. **Slave Brake System** In paragraphs 21-4 and 21-5, and 23-1, we touched on slave brake systems. One thing we mentioned is that the PBCV's were located near the landing wheel brakes. The dual brake control valve is remotely controlled by master cylinders. These are mechanically connected to the brake pedals. One advantage of this type system is that it is light in weight. Another is that there are no high pressure hydraulic lines in the pilot's compartment. Figure 106 shows one type of hydraulically operated (slave) power brake control valve. This valve is a dual unit that meters fluid in the same manner as other dual PBCV's. The difference between this valve and the usual brake control valve is the method of operation.



A Pressure inlet port
B Brake port
C Return port

Figure 105. Dual power brake control valve



A. Pressure inlet port (from main system)
B. Parking pressure inlet ports (from main system)
C. Slave and parking cylinders
D. Slave cylinder pressure ports (from master cylinder)
E. Actuating levers
F. Actuating lever spring assemblies
G. Return port to reservoir
H. Brake ports (2 each)

Figure 106. Hydraulically operated PBCV.

23-23. Each of the brake pedals of both pilot and copilot operates a separate master cylinder. Both pilot and copilot right master cylinders send fluid into the right slave cylinder pressure port (D), figure 106. Both pilot and copilot left masters cylinders send fluid into the left slave cylinder pressure port (D). When fluid enters either of the two ports marked "D," it forces a piston in a slave and parking cylinder (C) to move left. This pushes the upper end of an actuating lever (E), with its spring assembly (F), to the left. The lever is pivoted so the lower end moves to the right. Either lever causes the PBCV to meter main system fluid, which entered the pressure inlet (A), out through a brake port (H). From either port H (only front port shown), it flows to the right or left brake assembly. The force applied by the brakes is in direct proportion to the force applied on the brake pedal.

23-24. To apply the parking brakes, main system pressure is routed into parking pressure inlet ports (B). In the line upstream from ports B is an ON-OFF valve operated either manually or by a solenoid. It is called the *parking valve*. Opening it actuates the parking brake feature. Fluid entering ports B pushes the piston in the cylinder (C) against lever E and F. As in normal brake application, either lever causes the PBCV to meter fluid to the brakes. Again the source of fluid to the brakes is pressure inlet port A. When the brakes are released the fluid returns to the main system reservoir through the return port (G). An accumulator and check valve are located in the line attached at port A. This provides a supply of fluid under pressure for landing if the main hydraulic system has failed.

24. General Maintenance of Brake Valves

24-1. Check power brake valves, brake metering valves, and master cylinders for operation before taxiing or towing an aircraft. At periodic inspections, inspect them for leakage at the ports and around the piston rod. You must also periodically check both the maximum and parking brake pressures. To do this connect a pressure gage to the brake bleeder port and then apply normal and parking brake pressure. Of course, an adapter line will have to be connected to the gage and the bleeder port. Such a line can be manufactured locally.

24-2. You must also keep in mind that if any hydraulic brake line is disconnected, the system will have to be bled to insure proper operation. Next, we discuss some other specific maintenance operations.

24-3. **Inspection and Repair.** Like all other pneudraulic components, brake valves will have to be disassembled, cleaned, inspected, repaired, and tested periodically. They must be cleaned with an approved cleaning solvent. Then, they must be dried thoroughly with a clean, lint-free cloth or with compressed air. While the unit is disassembled, you inspect all parts for nicks, cracks, scratches, corrosion, and dirt. All threaded surfaces must be inspected for stripped, crossed, or otherwise damaged threads. All items included in the repair kit for that unit should be installed as replacements. Replace worn or damaged parts that cannot be reworked by lapping or honing to meet inspection requirements. Before reassembly, lubricate all internal parts with clean hydraulic fluid.

24-4. **Testing.** Various tests must be performed on all reassembled brake valves before they are put into use. One test is the proof pressure and external leakage test. Here the ports are plugged and the valve is pressurized for a length of time. The valve is checked for damage and leakage. Another test checks for internal leaks while the valve is pressurized. The final check is an operational check.

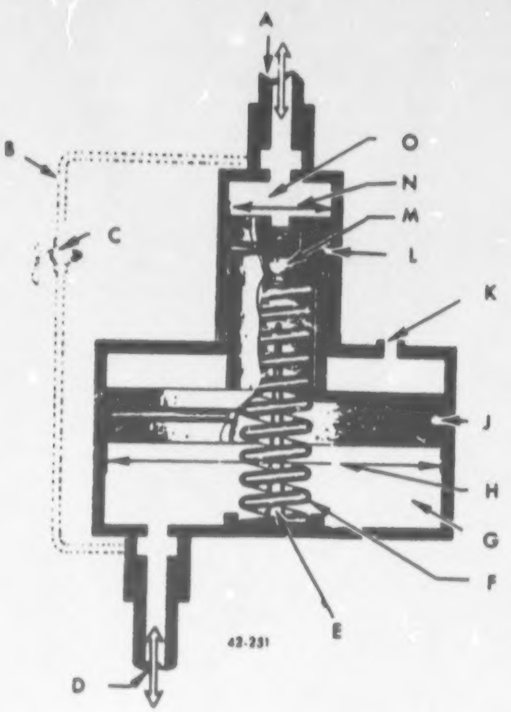
24-5. A hydraulic test stand such as the HCT—6 is required to perform these tests. (We do not go into detail; these tests vary for each valve.) You must follow the step-by-step procedure as given in the applicable TO. Maintenance of these valves is made easier if you follow the troubleshooting charts given in most TOs.

25. Deboosters

25-1. A debooster is used in an aircraft brake system to insure rapid application of the brakes. Also, it releases the brakes more quickly. The main aircraft system fluid supply coming from the PBCV or metering valve is high in pressure but small in volume. The same is true for the fluid coming from a master cylinder. Most aircraft do not need such high pressure going into the brake to lock the wheels. But, large aircraft with many wheel brakes require a large volume of fluid. The debooster solves this problem. It reduces the pressure but increases the volume to the brakes.

25-2. You may be wondering why it is so important to have the brakes apply and release so rapidly. Therefore, let's explain the situation. Braking action occurs by forcing a stationary surface against a rotating surface. We also know that all brakes have an *off* clearance. This is the actual distance between the rotating and the stationary surfaces when the brakes are not applied. The initial volume of fluid directed into the brake unit takes up only the off clearance. The larger the brake unit, the greater the amount of fluid required for this purpose. What happens after the stationary surface of the brake has made contact with the rotating surface? More fluid is forced in to give effective braking pressure. We must provide some means of getting a large volume of fluid into the brake unit during application rapidly. If we don't get the fluid in quickly during application, the braking action will be too gradual. This will result in excessive heating and wear of the brakes. The cause is *the extra drag on the brakes before effective braking takes place*. Likewise, we must get the fluid out quickly because brakes will drag if they are released slowly. This again causes more heat and wear.

25-3. This brings up what you learned in Chapter 1, Sections 4 and 5. Deboosters are practical examples of force-pressure-area-



A. Line from PBCV or metering valve
B. External line
C. Star valve
D. Line to brake assembly
E. Pin
F. Spring
G. Lower fluid chamber
H. Lower piston head
J. Seal
K. Air vent
L. Seal
M. Compensating valve
N. Upper piston head
O. Upper fluid chamber

Figure 107. Typical debooster.

length-volume relationships. They also demonstrate mechanical advantage or MA. Turn back and review these sections if your memory on these matters is fuzzy. On a piece of paper draw figures 3 and 4 and read how to apply them. Keep this paper before you as you read the material on deboosters.

25-4. **Operation.** Figure 107 illustrates a typical booster. A close look at it will help you to understand its operation. The main feature is the piston, which has two different areas. The upper area (N) and lower area (H) always differ in size. The size ratio of one piston to that of the other will vary according to need. Some ratios are 3:1; that is, the lower area is three times that of the upper area. Other ratios may be 6.7:1 or 4:1, depending on the design for a specific system. For instructional purposes, assume that the debooster in figure 107 has a 3:1 ratio. Pressure coming from the brake control valve enters the debooster at the metering valve port (A). It acts on the upper area of the piston. If the pressure coming in is 1200 psi and the upper area is equal to 1 square inch, the force developed will be 1200 pounds force ($P \times A = F$; 1200 psi × 1 sq. in. = 1200 lbs. force). With a 3:1 ratio, the lower area of the piston (H) is 3 square inches. The pressure developed on the bottom side will be 400 psi

$$\left(\frac{F}{A} = P;\ \frac{1200 \text{ lbs. force}}{3 \text{ sq. in.}} = 400 \text{ psi}\right).$$

This computation shows that the debooster has reduced or deboosted pressure.

25-5. However, this is not the most important factor. Suppose the piston is moved down a distance of 1 inch. One cubic inch of fluid will be required to accomplish this movement. ($A \times L = V$; 1 sq. in. × 1 in. = 1 cu. in.) At the same time, 3 cubic inches of fluid will be forced out the lower port (D). ($A \times L = V$; 3 sq. in. × 1 in. = 3 cu. in.) The main purpose has been accomplished, that of sending a larger amount of fluid to the brake assemblies. The brakes are applied quickly by the larger volume under a still adequate pressure. Rapid release is obtained by the reverse procedure. When the brake pedal is released, the 1 cubic inch of fluid in the upper chamber (O) is dumped back through the brake control valve. While the spring (F) moves the piston upward 1 inch, the lower chamber draws 3 cubic inches from the brakes.

25-6. The air vent (K) prevents a vacuum or high-pressure condition from building up behind the piston. Two seals (J and L) prevent the fluid in the two chambers from escaping out the air vent. When the brakes are released, fluid in the upper chamber (O) returns through the brake control valve to the reservoir. The fluid in the lower chamber (G) increases in volume when the brake is released. The spring (F) creates this added volume by forcing the piston upward.

25-7. **Fluid Replenishment.** If fluid leakage occurs anywhere below the debooster, the fluid must be replenished. We will explain how with most deboosters the replenishing is automatic. Leakage from the lower chamber will cause the piston to ride lower in its travel. The piston can move down to a point where the opening pin (E) will contact and open the compensating valve (M). Notice this valve is built like a simple ball check valve. Now compensating fluid can flow from the high side to the low pressure side of the piston. This flow will stop when enough fluid has entered chamber G to raise the piston and close the valve (M). When the valve closes, the lost fluid in the lower chamber will have been replenished. The chamber must be large enough to hold a little more fluid than maximum wheel braking requires. This prevents the piston from normally moving down far enough to open the compensating valve. Thermal expansion of the fluid in the lower chamber can easily open the compensating valve and be relieved. With this type of debooster no special procedure is necessary for bleeding. Whichever method of bleeding is used, the compensating valve will allow the fluid to reach the outlet.

25-8. The compensating valve and the opening pin may not be installed in some deboosters. If so, an external line (B), with a star valve (C), will connect the upper and lower chambers. The normal position of this star valve is closed. Normal operation of the debooster is the same as before, but replenishing is done manually. With this arrangement, it is necessary to open the star valve while the brakes are applied. This will direct pressure to both sides of the piston. Since the lower side is larger in area, the piston will be moved upward, replenishing the lower chamber. The star valve need only be opened a moment and must be closed after replenishing is completed. Should the star valve be left open, the brake unit would receive more pressure than normal. This could easily cause locked brakes that would damage the internal parts of the brake unit.

25-9. **Maintenance.** To bleed the brakes with this type of debooster, open the star valve; which will remain open throughout the bleeding procedure and closed thereafter. A thermal relief valve relieves expansion in the lower chamber of this debooster. It relieves a few drops of fluid overboard when pressure goes high enough. (The relief valve is not shown in figure 107.)

25-10. The debooster housing is actually constructed in two halves, bolted together. Take care during disassembly to hold the two halves securely when removing the bolts. The strong spring (F) tends to force the halves apart. All parts must be washed in an approved cleaning solvent, and seals must be replaced with new ones. Using an arbor press to hold the two halves together makes assembly easier. Testing procedure is set forth in the applicable TO for each model debooster. There you will find specific testing pressures applying to that particular debooster.

26. Brake Assemblies — Multiple Disc

26-1. In the preceding sections you learned how various brake systems and components are used. Their purpose is to deliver hydraulic pressure to the brake assemblies in proper quantity. These brake assemblies must operate at a high degree of efficiency. And they must do so with a minimum amount of lining wear. They must also be highly resistant to the condition known as *brake fade*. This is a gradual loss of braking action due to overheating. However, there is one more thing to mention before discussing the brake assemblies: how the laws of physics tie into the overall hydraulic braking system.

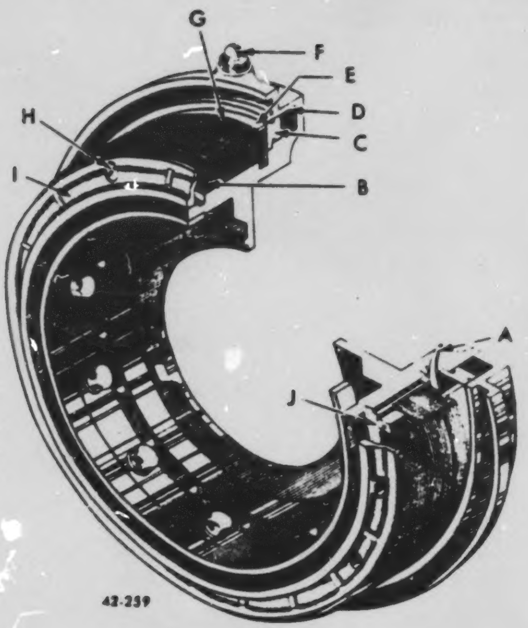
26-2. **Physical Principles.** One of the basic laws of physics states that any body in motion has kinetic energy. Thus, a bullet in flight has energy, and this energy is expended when it hits an object. Likewise, a moving aircraft or automobile has energy that is expended when it stops. Therefore, the motion of any body ceases when its kinetic energy has been expended. One of the best ways to dissipate this energy is to convert it into heat. Brakes convert the kinetic energy of a moving aircraft into heat. The amount of energy contained depends upon the weight (mass) of the aircraft and its speed (velocity). Thus, the amount of heat generated to stop the aircraft depends solely upon these factors. The brakes must be of a correct size and design to handle this heat. Better brakes are designed to tolerate high temperatures and to dissipate the heat rapidly.

26-3. You have no doubt watched large aircraft rolling down the runway after landing. Did you ever think about how much heat was geing generated from the braking action? It's probably a lot more than you ever thought. It is enough to raise the temperature of a seven-room house from freezing to around 70°. The friction and heat causes braking materials to wear away, warp, and deteriorate. As the pneudraulic mechanic, you adjust, inspect, reline, and replace these brakes.

26-4. Now what are the various types of brake assemblies used by the Air Force? The first one that we will discuss is the multiple disc type.

26-5. **Construction and Operation.** The multiple disc brake contains a number of metal discs. Some of these discs are bronze plated and are keyed to rotate with the wheel. The remaining discs are made of steel. These steel discs are spaced alternately between the bronze discs and do not rotate. Figure 108 illustrates a typical multiple disc brake.

26-6. Braking takes place when fluid under pressure is introduced behind the annular ring shaped piston (C). The fluid forces the piston to the left. This movement creates friction bet-



A. Piston return spring
B. Stationary steel disc
C. Annular piston
D. Piston cup seal
E. Insulating ring
F. Bleed screw
G. Rotating bronze disc
H. Retaining nut lock screw
J. Retaining nut
K. Anchor key

Figure 108. Cutaway of a multiple disc brake.

ween the rotating bronze discs (G) and nonrotating steel discs (B). This friction causes the bronze discs to stop turning, and since they are keyed to the wheel, it also stops turning. The amount of braking action is directly proportional to the amount of pressure admitted to the brake.

26-7. The braking friction between the discs generates a large amount of heat. An insulating ring (E) is provided to prevent the fluid behind the piston from absorbing the heat. If the insulating ring were not included, the temperature of the fluid would become so high that it would boil when the brakes were released. This would have the same effect as air in the brake assembly; the braking action would be spongy.

26-8. The number of steel discs is one greater than the number of bronze discs. This is because one stationary disc is needed on each side of the stack.

26-9. You may ask this question, "Why do we use discs of unlike metals?" The answer lies in the molecular construction of the metals. Any time friction occurs between two like metals, galling, scoring, or metal pickup will take place. This problem is greatly reduced between unlike metals. Bronze and steel have been found to be one of the better combinations to use for disc brakes.

26-10. Multiple disc brakes have one big disadvantage: the extreme warping of the discs which takes place when they are overheated. Much of this is due to the brake's having a large friction area and poor heat-dissipating qualities. Long, hard application of the brakes will cause the discs to become very hot. But, they should not be artificially cooled, as this will warp them.

26-11. **Maintenance.** Access to the brake assembly is gained by removing the wheel. This should be done according to instructions contained in the TO for the aircraft concerned. To inspect and repair the brake, it should be removed from the aircraft. To do this, disconnect the hydraulic line and detach the whole brake assembly from the axle torque flange.

26-12. Refer again to figure 108. To disassemble the brake, start by removing the disc retaining nut lock screw (H); then manually unscrew the disc retaining nut (I). The stationary and rotating discs can then be lifted from the housing. Next, remove the fragile insulating ring, using extreme care. Follow instructions in the TO covering the brake to remove the piston and piston seal.

26-13. When all metallic parts have been cleaned, they should be carefully inspected. Check the anchor keys (j) for notching and wear. They must be replaced if worn or grooved 0.002 inch. At this time, tighten the anchor key bolts to the torque specified for the brake

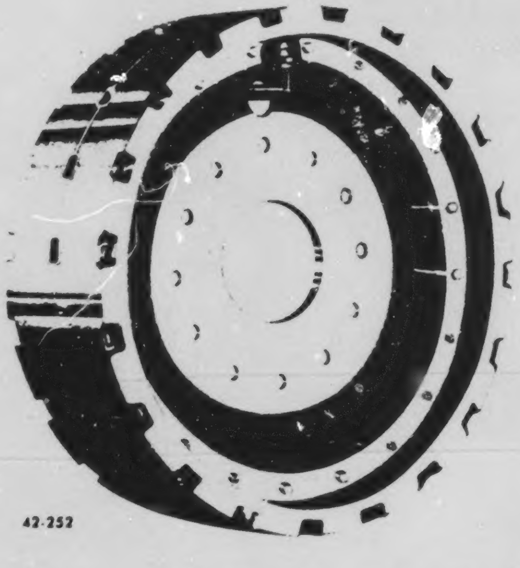
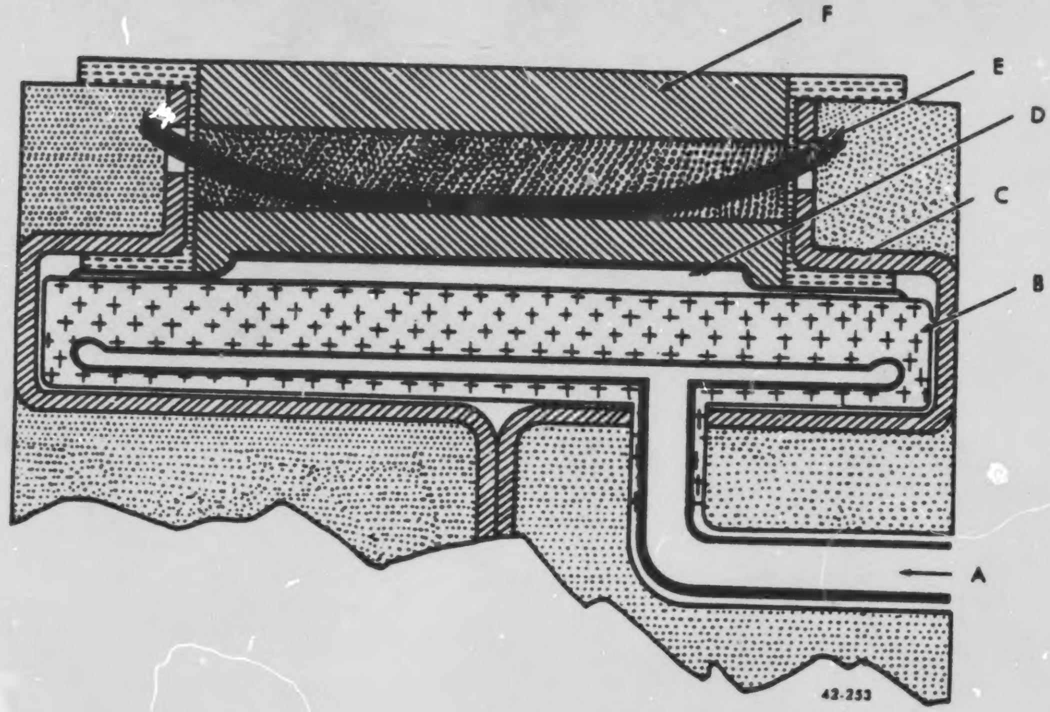


Figure 109. Duplex expander tube brake assembly.



A. Fluid inlet
B. Expander tube
C. Brake frame
D. Expander tube shield
E. Retractor spring
F. Brake block

Figure 110. Cross section of an expander tube brake.

assembly being inspected. Then inspect the discs for wear and evidence of warping. If the warped discs cannot be tapped flat with a hammer, replace them. Any bronze-coated discs that have worn 0.020 inch must also be replaced, as they will not have enough coating remaining. Any return springs (A) that show damage or signs of rust must be replaced. The piston cup seal (D) need not be replaced unless it shows signs of wear, shrinkage, cracking, or remolding.

26-14. When reassembling the brake, rigidly follow the TO instructions. The most important step is the proper installation of the piston seal. Take care to stack the discs in proper sequence, as steel discs must begin and end the stack.

26-15. Adjust the brakes by turning the retaining nut (I) to give a specified clearance between it and the adjoining steel disc. Two feeler gages are used to measure this clearance. They must be placed directly opposite each other at the same time. When the clearance is correct, the retaining nut lock screw (H) is tightened to the TO torque value. The brake is then tested according to the procedure given in the TO. If the test is successful it is ready for installation on the aircraft.

27. Expander Tube Brakes

27-1. The expander tube brake is shown in figure 109. This type of brake assembly consists of three main parts: the brake frames, the expander tube, and the brake blocks. It is manufactured in both single and duplex models. The single type has one row of brake blocks, while the duplex has two rows. This particular brake is also made in the dual duplex

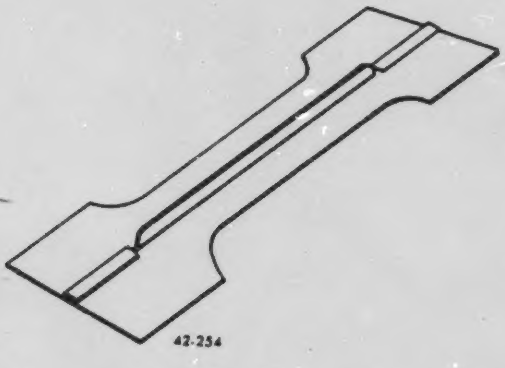


Figure 111. Expander tube shield.

type. It consists of a duplex brake on both the inboard and outboard side of the wheel. A brake adjuster valve is incorporated in the design of some expander tube brakes. There is no provision for adjusting the brakes that do not have these adjusters.

27-2. **Operation.** A cross-sectional view of the expander tube brake is shown in figure 110. Braking takes place when fluid pressure is directed into the fluid inlet (A) and into the expander tube (B). As the tube is restrained from inward and sideward movement by the brake frame (C), the tube expands outward. This forces brake blocks (F) outward against the brake drum, causing the friction which stops wheel rotation. The brake blocks are prevented from turning with the drum by torque lugs on the brake frame.

27-3. When the brake pedal is released, fluid pressure is relieved from the tube. Semielliptical retractor springs (e) are fitted through slots in the ends of the brake blocks. When the tube depressurizes, the retractor springs retract the blocks. This action causes the expander tube to deflate, and the brake returns to it OFF position. Expander tube shields (D) are placed under the ends of adjoining brake blocks. (An example of an expander tube shield is shown in fig. 111.) They prevent the tube from squeezing out between the brake blocks, where it could be pinched as the blocks move.

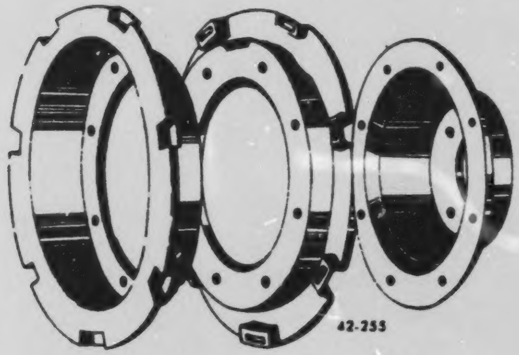


Figure 112. Stamped brake frame.

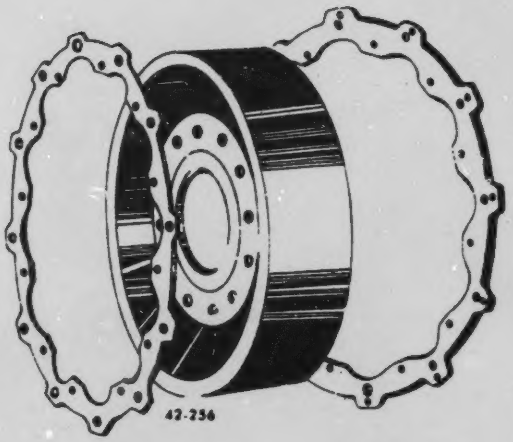


Figure 113. Cast brake frame.

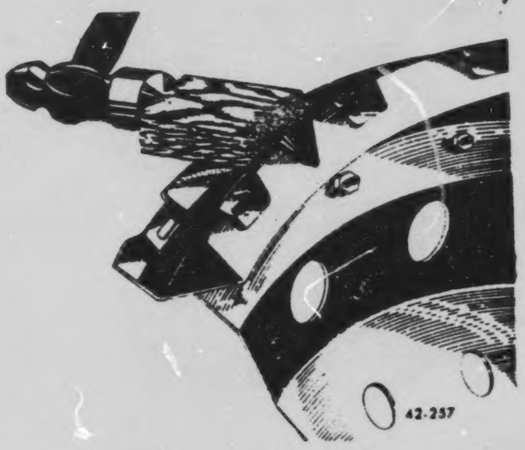


Figure 114. Method of removing dents from brake frames.

27-4. On some expander tube brakes, no provision is made for adjustment. When new brake blocks are installed on the nonadjustable-type expander tube brake, a new tube is also usually installed. The new blocks are then turned down to provide the correct clearance. The clearance is 0.002 inch to 0.015 inch between the blocks and the drums. Because the expander tube swells as it ages, it somewhat compensates for lining wear. Check the thickness of the brake blocks whenever the brake clearance exceeds 0.075 inch. First determine the maximum distance the retractor springs can deflect. If the thickness of material worn from the blocks is equal to the above distance, replace the blocks.

27-5. **Inspection and Maintenance.** Brakes that have stamped frames (see fig. 112) may be inspected or relined without removing the brake from the landing gear. However, the wheel must be removed. Brakes that have cast torque spiders (frames), as shown in figure 113, must be removed from the aircraft before they can be inspected or repaired.

27-6. For inspection, first remove the wheel (stamped frames) or the brake assembly (cast frames). Then check the entire brake assembly for corroded, broken, or distorted parts. Each retractor spring that is broken or rusted must be replaced. Instructions for the removal of the springs and brake blocks are given in the brake TO. Two or more blocks are to be removed and measured for wear. While the tube is exposed, examine it for signs of excessive brake heat. If the tube cover is burned, charred, or otherwise damaged, replace it. Test the expander tube for leaks by using compressed air and immersing the tube in a tank of water. Do not exceed 75 psi. Remove dents in the brake frames by placing the wooden block against the bulge of the dent, then tapping the block with a hammer. This method of dent removal is illustrated in figure 114. When assembling the brake, be careful not to place a thick brake block next to a thin one (this creates undersirable strain on the expander tube and retractor springs). The periods specified for brake inspections and their scope are found in the brake TO. The time between major overhauls depends upon the type of aircraft operation and the location.

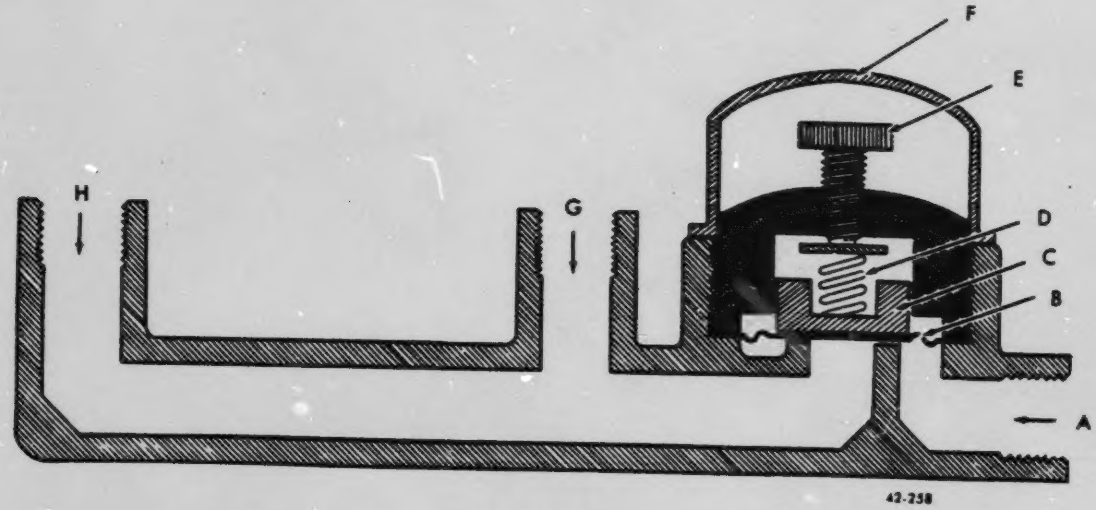
27-7. **Brake Adjuster Valves.** Brake adjuster valves are installed on many expander tube brake assemblies. They are simply adjustable, two-way relief valves, which always trap a small amount of fluid pressure within the expander tube. This prevents the brake blocks from returning completely to the retracted position. Figure 115 shows a cutaway of an adjuster valve used on a duplex expander tube brake.

27-8. As braking pressure is applied, fluid enters the inlet port (A) of the brake adjuster valve. The entering fluid pressure easily raises the diaphragm (B) and spring plunger (C) against the force of the spring (D). The fluid then enters the expander tube through ports G and H.

27-9. When the brakes are released, the expander tube is compressed by the retractor springs. The springs create enough pressure on the fluid to force most of it back through the expander valve. But, the spring (D) is strong enough to trap the last fluid in the tube. By retaining a quantity of fluid, the tube remains partially inflated. As a result, it holds the brake blocks closer to the brake drum.

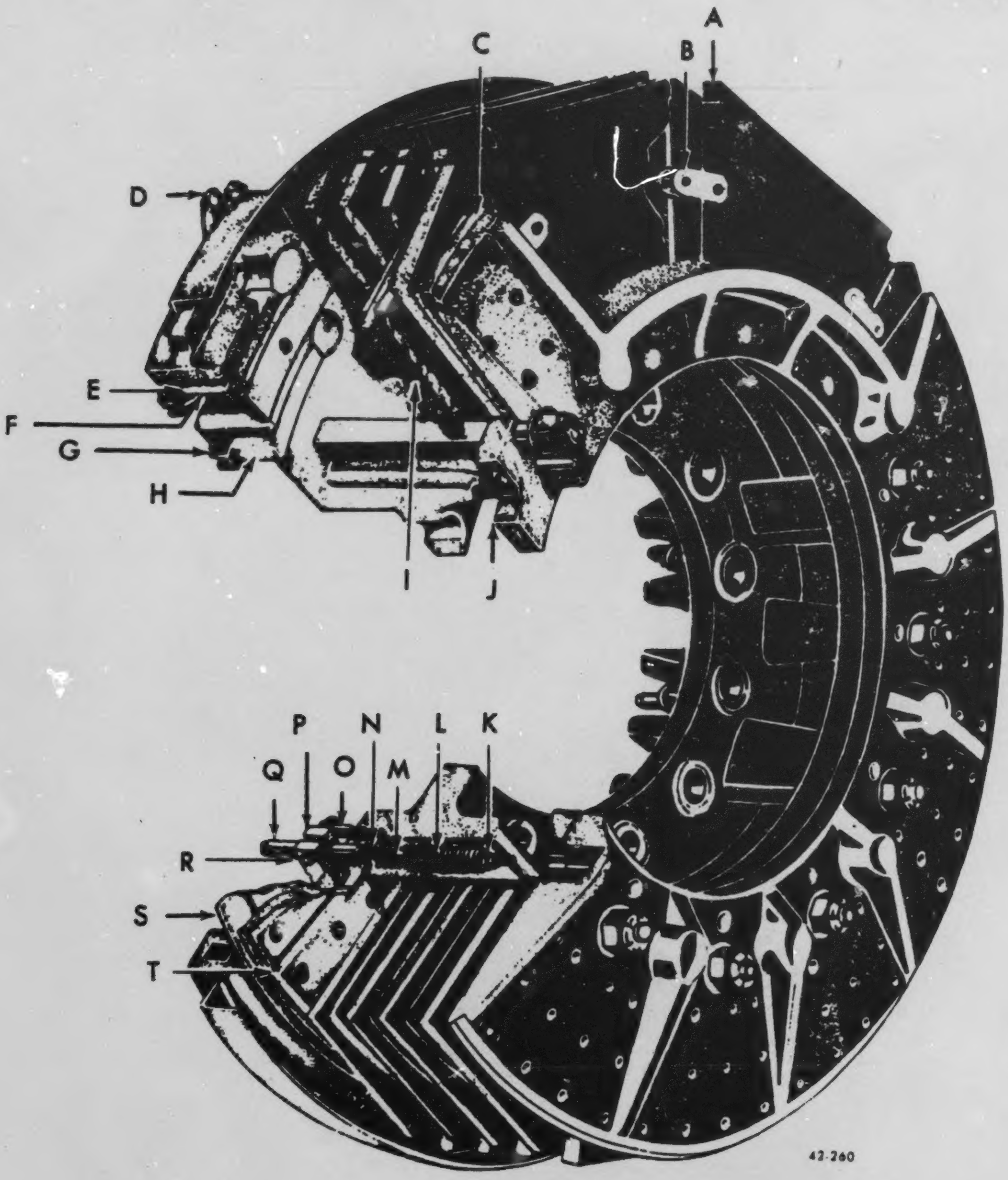
27-10. The adjusting screw (E) is turned to increase or decrease spring tension. This increases or decreases the amount of fluid trapped in the expander tube. Remember that the amount of fluid determines the distance the friction blocks are from the brake drum. Therefore, adjust the brake clearance by turning the adjusting screw (E).

27-11. **Adjusting Expander Tube Brakes — Using Brake Adjuster Valve.** The first step in the adjustment is to release the brakes and remove the brake adjuster valve cap (F). Then turn the brake adjuster screw several turns clockwise to tighten the spring (D). This position of the adjustment screw will cause the maximum quantity of fluid to remain in the ex-



A. Inlet port from brake control valve or master cylinder
B. Diaphragm
C. Spring plunger
D. Spring
E. Adjusting screw
F. Cap
G. Expander tube port
H. Expander tube port

Figure 115. Brake adjuster valve.



A. Rotor segment
B. Rotor link
C. Backing plate assembly
D. Bleeder screw assembly
E. Piston cup (outer)
F. Piston (outer)
G. Piston cup (inner)
H. Piston (inner)
I. Stator plate
J. Compensating shim

K. Adjuster nut
L. Adjuster return spring
M. Adjust sleeve
N. Adjuster washer
O. Clamp holddown assembly
P. Adjuster clamp (friction block)
Q. Adjuster pin
R. Adjuster screw
S. Pressure plate
T. Auxiliary stator and lining assembly

Figure 116. Cutaway of the segmented rotor brake assembly.

pander tube. Now depress the brake pedal several times, to fully expand the expander tube. If this puts the brake blocks against the drum, you are ready to release the brakes and slowly turn the adjusting screw counterclockwise. This permits the brake blocks to retract away from the drum. Keep checking with a feeler gage inserted between the brake blocks and drum. When the *minimum* clearance specified in the aircraft TO is obtained, stop turning the screw. Then with the weight of the aircraft on the wheels, reapply the brakes several times. Now recheck the clearance to insure a uniform minimum clearance. Make clearance checks about 30 seconds after brakes are released to insure complete retraction of the brake shoes. If the minimum clearance will not hold, you probably have a leaking adjustment valve. In that case it should be replaced.

27-12. To many of you, information concerning the expander shoe-type brake may have been new. This is probably not the case with the next type of brake we are going to discuss. It is used in the coaster brake on bicycles and also on many new cars.

28. Segmented Rotor Brakes

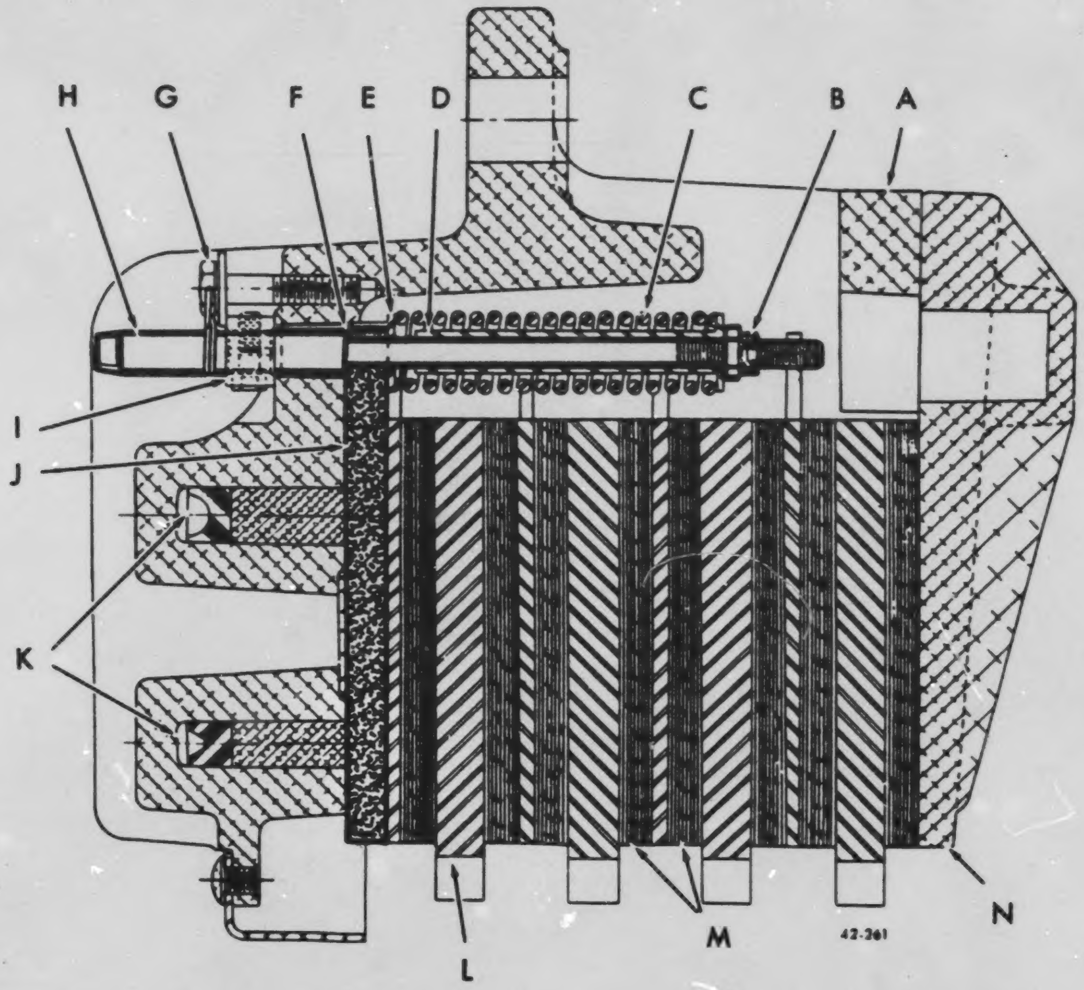
28-1. The segmented rotor brake operates on the multiple disc brake principle. It has rotating segments that are squeezed between stationary discs. Figure 116 illustrates the segmented rotor brake assembly. The segmented rotor type has a large amount of braking surface within a comparatively small diameter. In this it resembles the multiple disc brake. Because they are made of thick metal segments linked together, we don't have warping of the rotation discs. These segmented discs are called *rotors*. B in the figure indicates the rotor links. The stationary discs (stators) have lining material riveted to them and they maintain a constant *off* clearance. These are advantages over the multiple disc brake.

28-2. Refer to figure 116. We see that the linked rotor segments (A) are sandwiched between the stators (I) and are keyed to rotate with the wheel. During brake application, fluid is directed to the left-hand side of the piston cups (E) and (G). It then forces the semiannular pistons (F and H) to the right. This causes the sandwiched stators (I) and rotors (A) to be squeezed between the pressure plate (S) and the backing plate (C). The friction produced by this squeezing action causes rotating segmented rotors to slow down. Since they are keyed to the wheel, it also slows down. The resistance developed is directly proportional to the amount of pressure of the fluid behind the pistons. This, as in other brakes, the braking action can be gentle or severe, depending upon the pressure metered to the brake assembly. D indicates the brake bleeding points. Callouts J, R, Q, P, O, N, M, L, and K are shown in better detail in figure 117, which is a cutaway of the rotors and discs.

28-3. **Operation of the Automatic Adjuster Mechanism.** Figure 117 gives a detailed illustration of the automatic adjuster mechanism (shown in the lower left-hand portion of figure 116). This adjuster is designed to maintain a fixed clearance when the brake is in the unapplied (OFF) position. As the brake linings wear, the adjuster automatically compensates for this wear. It maintains a uniform *off* clearance and a constant fluid requirement per brake application. These adjuster mechanisms are located in intervals around the brake assembly. Earlier models had a shim (A) installed to lengthen wear life, but new adjusters eliminated the shim.

28-4. Figure 117 shows that the adjuster pin (H) is inserted through a hole in the pressure plate (J). During brake application this action occurs. The pistons (K) shove the pressure plate (J) and the washer (E) to the right, against spring force, until it contacts the sleeve (D). This movement eliminates the brake clearance but does not apply hard braking. To apply the brakes firmly, the pressure plate (J), pushing against the sleeve (D), must force the entire adjusting pin (H) to the right. The friction block (I) clamps the adjusting pin firmly. So, the piston force must be strong enough to slide the adjusting pin tight through the clamp. Thus, each time the brakes are applied, the adjuster pin is moved inward a *very* slight amount. This allows the stators and rotors to be firmly compressed. From this you can see that pin H will not move far during a single brake application. It will move just far enough to make up for the loss of brake lining worn away during the preceding application. Thus, the brakes are kept adjusted.

28-5. As pressure is relieved from behind the pistons (K), the spring (C) forces the pressure plate (J) back. It moves left until it hits shoulder (F) of the adjusting pin. Because of the adjusting pin's movement to the right, the pressure plate (J) will no longer rest against the brake housing. Likewise, the pistons will begin to protrude slightly from their cavities to follow the pressure plate. From this discussion we see that as the linings become thinner, the movement range of the pressure plate moves to the right. But, since the distance between the sleeve and the shoulder does not change, the



A. Compensating shim
B. Nut
C. Piston return spring
D. Sleeve
E. Washer
F. Shoulder of adjuster pin
G. Clamp holddown assembly
H. Adjust pin
I. Adjust clamp (friction block)
J. Pressure plate
K. Piston
L. Rotor
M. Lining blocks
N. Backing plate

Figure 117. Automatic adjuster of the segmented rotor brake.

pressure plate range remains constant. It always backs off the same distance after each application. This gives a uniform *off* clearance.

28-6. As we said, the distance between the sleeve (D) and adjuster pin shoulder (F) determines the off clearance. This distance is the range through which the pressure plate (J) slides. It is adjusted during brake assembly by turning the adjuster pin nut (B). To adjust it, first tighten down the nut until the pressure plate is pinched between the sleeve and shoulder (F). This gives us no clearance. Then back off the nut a specified number of turns to give the proper clearance. Once this adjustment is made, it should hold during the life of the brake lining. However, if the adjuster is to work, you *must* exactly torque the adjuster clamp (I). If the adjuster clamp is undertorqued, the pin (H) will move too far to the right at each brake application. The adjuster pin will be pulled to the right by the spring (C). This will eliminate the off (running) clearance and cause the brakes to drag. If the adjuster clamp is overtorqued, friction on the adjuster pin will be too great. Then hydraulic pressure cannot move the pin to the right to compensate for lining wear. This hindrance will cause braking friction to decrease (fading brake) as the linings wear, which eventually will result in the complete loss of braking action. The clamp holddown assembly (G) prevents slippage of the adjuster pin back to the left. It prevents the weight of the rotors (L) upon the pressure plate from forcing the adjuster pin to the left when the wheel is retracted, which consequently would nullify the purpose of the automatic adjusters.

28-7. Lining blocks are riveted to both sides of each stator (with the exception of the auxiliary stator, item T, fig. 116). Numerous lining blocks (M) are shown in the cross section of the brake, figure 117. If each of the lining blocks wears 1/16 inch, there is still much useful lining remaining. But, since there are eight blocks, the total lining thickness that has been worn away is 1/2 (8/16 inch). This means that the adjuster pin will be 1/2 inch further to the right. The pistons will protrude 1/2 inch from their cavities, which is not good. So, measure the amount of pin H showing on the outside of the friction clamp. The TO tells you how much of the pin must show. When the adjuster pin has moved in the permitted distance, it is time to reline the brake. At one time we were allowed to remove the compensating shim (A) from the backing plate (N) (allowing H to be moved back) to get some more wear out of the lining. However, *this is no longer permitted.*

28-8. **Maintenance of Segmented Rotor Brakes.** Complete disassembly, inspection, overhaul, and repair instructions for segmented rotor brakes are contained in the brake TO. When internal inspection or maintenance is necessary, the brake must be removed from the aircraft. This is done in accordance with the maintenance instruction TO for the aircraft. A table of dimensions and specifications in the brake TO gives information on permissible wear, cracks, distortions, running clearance, and so forth. Remember, brakes are always to be returned to service in like-new condition.

29. Spot Disc-Type Brakes

29-1. Spot disc-type brakes are similar in action to the multiple disc-type and segmented rotor-type brakes. A typical brake of this type is shown in figure 118. One or two steel discs are generally used. This depends on the type and size of the aircraft on which the brakes are installed. These discs, which are keyed or fastened to the wheel, rotate with the wheel. The brake cylinder housing contains one or more brake actuating pistons. It is securely bolted to the torque plate of the aircraft landing gear. The piston squeezes the rotating steel discs between stationary brake linings to produce braking action. The force is applied to the flat surface of the steel disc at the spot where the actuating pistons are located. Spot disc-type brakes have from one to four pistons and corresponding spots. The number of pistons also depends on the type and size of the aircraft.

29-2. Single disc brakes are of several types. They are classified as single disc mechanical, single disc booster, and single disc hydraulic brakes. In addition to these wheel brakes, there is also a single disc brake for helicopter rotors. The helicopter rotor brake disc is bolted directly to the rotor shaft.

29-3. Dual disc brakes are hydraulically operated and are always of the multiple cavity (piston) type. However, their construction is essentially the same as that of the single disc brakes. The dual disc brake has two rotating discs and two sets of brake linings. They are used on aircraft which require more braking friction at lower pressure than is provided by the single disc brake.

29-4. The single disc booster brake is a multiple cavity hydraulically operated brake which has servo action. This brake was an advancement when it was first introduced, since the servo action provided a relatively high braking friction when used with a master cylinder brake system. It, in fact, increased or boosted the pressure supplied by the master cylinder. Now, however, power braking systems can deliver any desired pressure to the brake assemblies. So, servo brakes no longer offer an

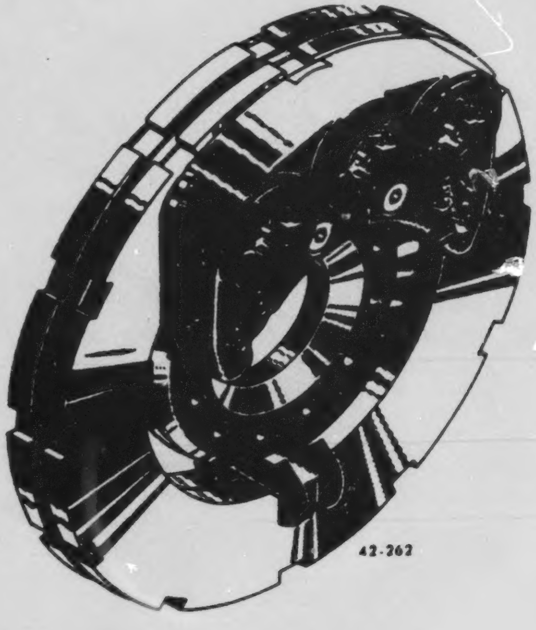
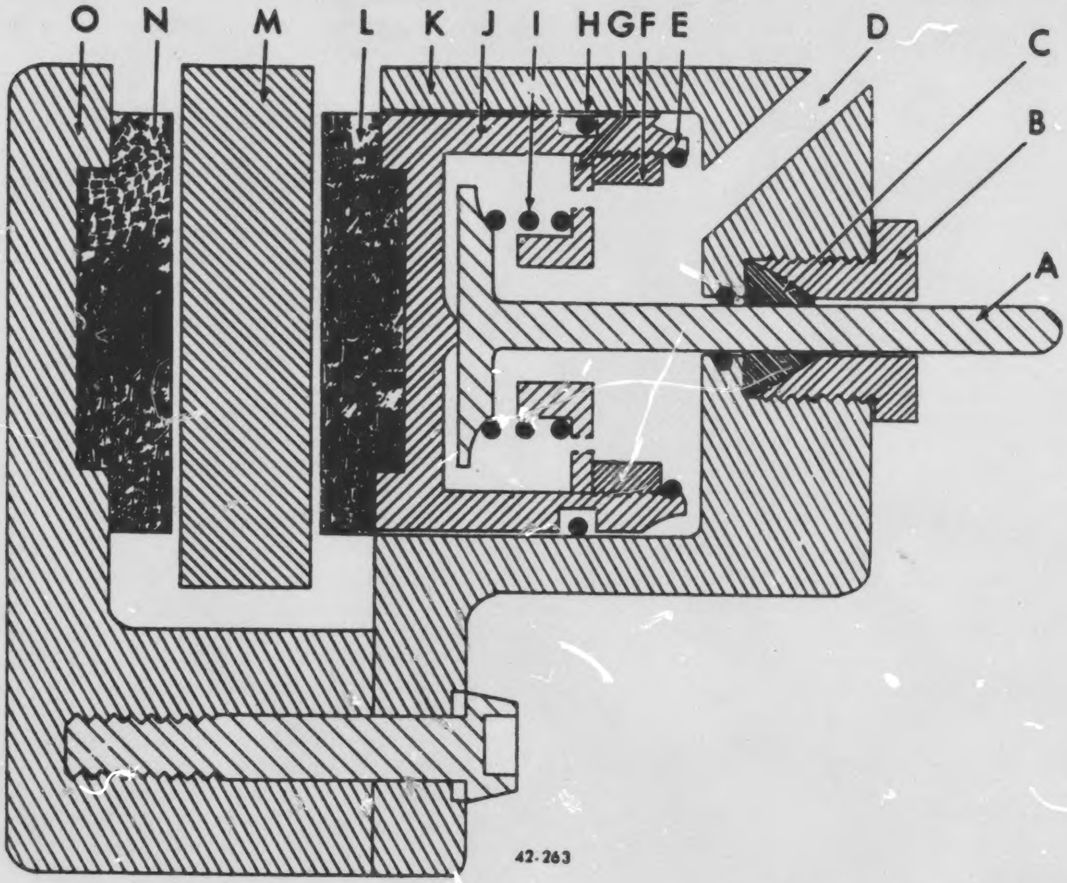


Figure 118. Triple spot disc brakes.



A. Self-adjusting pin
B. Self-adjusting pin nut (torque nut)
C. Self-adjusting pin grip
D. Fluid port
E. Internal retaining ring
F. Threaded retaining ring
G. Spring guide
H. Piston O-ring packing
I. Brake release spring
J. Piston
K. Brake cylinder housing
L. Brake lining
M. Rotating brake disc
N. Brake lining
O. Backing plate

Figure 119. Cutaway of a single disc brake.

advantage. For this reason newer aircraft do not need the more complicated and expensive booster (servo) brakes.

29-5. The single disc, mechanically operated brake is used only on small aircraft, such as light liaison types. It consists of a single cavity housing containing conventional brake lining "pucks." Braking action takes place when the brake pedal is depressed. The force on the pedal is transmitted through a rod or cable linkage to a lever on the brake assembly. The lever forces a pushrod against the outboard brake lining. This, in turn, forces the rotating disc against the inboard lining. The friction developed causes resistance to disc rotation and hence resistance to wheel rotation. This braking action is primarily the same for either mechanical or hydraulic brakes.

29-6. An outstanding feature of the spot disc-type brake is its rapid heat dissipation. As you can see by figure 118, most the wheel disc is exposed to the air during application.

29-7. **Operation of the Automatic Adjusting Mechanism.** A schematic cross section of a single disc, hydraulically operated brake is shown in figure 119. This brake, like most hydraulically operated single and dual disc brakes, is self-adjusting. The illustration shows a cutaway of only one piston cavity. However, all piston assemblies of this type of brake are nearly identical. Therefore the explanation of figure 119 may be applied to all of these assemblies.

29-8. Application of the single disc brake (Fig. 119) occurs when hydraulic fluid under pressure enters the fluid port (d). This fluid forces the piston (J) to the left, against spring pressure, until the spring guide (G) contacts the face of the adjusting pin (A). In moving this distance, the piston has also forced outboard brake lining L against the steel disc (M). It, in turn, moves sideways on its keys and contacts inboard brake lining N supported by the backing plate (O). Thus, the brake running clearance is taken up by this first movement of the piston. To obtain full braking friction between the rotating disc and the lining "pucks," the piston must move further to the left. The disc must be firmly pinched between the lining "pucks." However, the spring guide (G) is already contacting the face of the adjusting pin. Therefore the piston must carry the adjusting pin slightly to the left to provide this full braking action. The adjusting pin is held firmly by the friction of the adjusting pin grip (C). But, pressure on the piston provides enough force to overcome this friction. This allows the piston and pin to move further to the left. If the brakes are held in the applied position, the lining wears away. The pin continues to move inward slowly to compensate for the small amount of lining wear.

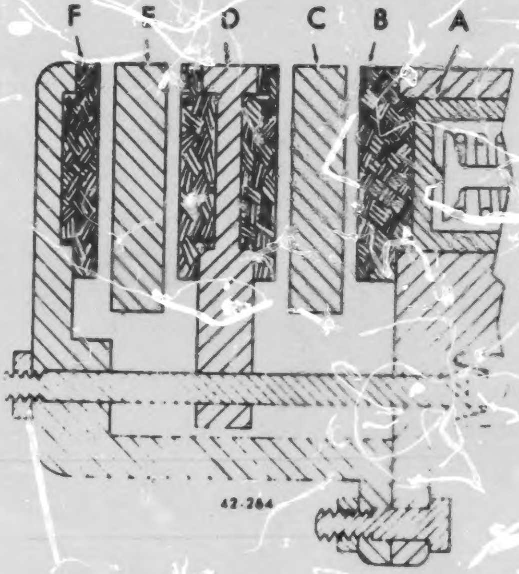
29-9. What happens when brake pressure is released? The force of the brake release spring (I) against the flange of the spring guide (G) will move the piston to the right. This relieves the disc of the pinching action of the brake lining "pucks," and the wheel will be free to rotate.

29-10. Every brake application carries the adjusting pin a little to the left to compensate for lining wear. Each time the brakes are released, the piston backs away from the outboard lining block. It can move until the back of the piston head contacts the face of the adjusting pin. Thus, the piston always releases to give the same running (off) clearance. The self-adjusting pin grip (C) should prevent the pin from moving to the right.

29-11. It is very important that the self-adjusting pin nut (B) be properly torqued. If the nut is too loose, there will be insufficient friction on the pin. This will permit the adjusting pin to be drawn inward by the spring, thereby eliminating the clearance to allow the brake to drag. If the nut is too tight, friction on the pin will be too great. In this case, hydraulic pressure may not be able to move the pin inward to compensate for lining wear. This will cause braking friction to decrease as the linings wear, and finally result in the complete loss of brakes. Torque values for the self-adjusting pin nuts are found in the brake TO. The threaded retaining ring (F) supports and positions the spring guide (G). The internal retaining ring (E) locks in the threaded retaining ring (F). The O-ring (H) prevents oil leakage from the piston.

29-12. Operation of the self-adjusting mechanism is the same for both the single and dual disc brake. The running clearance of the dual disc brake is usually greater than that of the single disc-type. This is because clearance must be provided on both sides of each disc. The housing of the dual disc brake has a larger U-slot cutout than the single disc brake. It must provide room for rotation of both discs, as is shown in figure 120. Dual disc brakes also have a center lining carrier placed between the two discs. This center carrier (D) has brake linings on both sides and is free to move sidewise, though it is prevented from rotating. Thus, as the brake is applied, the piston (A) forces the outboard lining block (B) against the outboard disc (C). The disc, in turn, moves against the center lining carrier (D). As piston movement continues, the carrier is forced against the inboard disc (E), which moves sidewise until it contacts, the inboard lining (F). This eliminates the brake running clearance. Further movement of the piston causes the discs to be firmly squeezed between lining surfaces and by so doing applies the brake.

29-13. Maintenance of Spot Disc-Type Brakes. Brake linings are replaced on disc brakes when the adjusting pins have moved in-



A. Piston
B. Outboard lining block
C. Outboard disc
D. Center lining carrier
E. Inboard disc
F. Inboard lining

Figure 120. Cutaway of a dual disc brake

ward to a specified point. The pins move inward as the linings wear. Thus the length of pin exposed shows the thickness of lining material remaining. The TO will give the distance the pins must extend to indicate sufficient lining thickness. When the pins show the minimum extension, replace the linings.

29-14. To properly disassemble, inspect, and repair one of these brakes, you must remove the wheel from the axle. Consult the appropriate maintenance instruction TO.

30. Maintenance of Brake Assemblies

30-1. A high percentage of aircraft accidents and maintenance problems are caused by wheel and brake failures. Many of these failures result from poor maintenance and careless inspection. We cannot overemphasize the need for better and more conscientious mechanics who know the following procedures and facts.

30-2. Brake assemblies are manufactured from magnesium, aluminum, and steel. Almost all have magnesium housings that are very easily corroded, especially in the piston cavities. The manufacturer surface treats these assemblies to provide a corrosion-resistant surface. However, this surface is easily scratched, creating a potential corrosion area. Therefore, all aircraft brake units must be thoroughly cleaned and inspected whenever work is done on the brake.

30-3. **Cleaning and Inspection.** Thoroughly clean disassembled brake parts with a brush or spray, using cleaning solvent, Specification P—S—661. Remove all blistered, chipped, or loose paint. Never use leaded gasoline for cleaning because the residual film leads to corrosion. After you thoroughly clean the brake parts, visually inspect the brake housing for cracks, chipped or worn mounting holes, stripped threads, and corrosion. Some corrosion is usually found in the carrier housing and in the piston cavities.

30-4. Corrosion pits or scores in the piston cavity area where the seals or cups contact the cavity walls cause leakage. These brakes must be returned to the repair depot for reconditioning. Piston cavities usually do not corrode heavily except when the brake is in extended storage, either on the aircraft or in stock.

30-5. Heavy corrosion is defined as pits that exceed 0.025 inch in diameter. Or, it can be groups of three or more pits of any dimension in an area of 1/4 square inch. Corrosion pits are usually filled with a yellow or grey residue in powder form. It calls for good judgement to decide to continue (or discontinue) an aircraft brake with heavy corrosion in the carrier housing and in the piston cavity area where seals and cups do not contact the cavity walls. Such a decision must be weighed against operational commitments, availability of replacements, and location and extent of corrosion. The decision to operate a corroded brake should be made by a qualified inspector or a maintenance officer.

30-6. **Repair and Surface Treating Brake Assemblies.** Inspect all steel parts for corrosion, which should be removed with a wire brush. Then repaint the steel parts with two light coats of zinc chromate primer, Specification MIL—P—8585A. Rework damaged areas where *minor* dents, nicks, burrs, or gouges are. Remove all sharp edges and indentations which might result in a concentration of stresses. This is done by first using a smooth-cut hand file and then using fine emery paper. Those assemblies having *deep* scratches, gouges, or cracks exceeding established limits must be removed from service. They will be disposed of according to existing publications. All metal surfaces will be surface treated according to corrosion preventive procedures.

30-7. Replace all seals, cups, and O—rings when you assemble brake assemblies. Take care when you install cup seals to prevent damage to the feathered edge. Apply a light coat of silicone compound, Specification MIL—I—8660, to the surface of the piston cavity and all seals. This provides additional protection against corrosion while the brake assembly is in storage. On spot disc and expander tube brake assemblies, condemn the opposite half when either half is condemned.

30-8. Brake assemblies which have been returned to the depots on a timely basis give longer service life. This results from the added surface treatment and processing procedures provided by the depot. The reliability of brakes is increased when the brake is returned to the depot on time. Tests show this should be done *before* the third lining change or the third piston seal change. The service life of a brake assembly depends entirely on the quality of the workmanship. The replacement parts are designed to give maximum service life.

30-9. **Use of Wheel Brakes and Wheel Firefighting Procedures.** Respectful treatment of aircraft brakes often prevents damage to equipment and injury to personnel. All personnel must be thoroughly familiar with braking instructions, and they should also keep the wheels and brakes under constant observation at all times.

30-10. Temperatures in excess of 250° F are detrimental to all wheels and tires. Heat transfers from the brake to the wheel and tire for a long time after brake application. Peak temperatures are not attained in the wheel and tire until 10 to 15 minutes after the stop. Very high temperatures are a danger and can cause the wheel and tire to explode or burn. Aircraft heavily braked should not be taxied or towed until the brakes have properly cooled. Never set the parking brakes when the wheels and brakes are in a heated condition.

30-11. Aborted takeoffs often require excessive brake action. In such a case, fire equipment should be sent at once if fire is seen or not. All other personnel should evacuate the immediate area. An overheated wheel and brake (with tire inflated) should be approached only from the front or rear.Both sides of the wheel must be cleared of personnel and equipment for at least 300 feet.

30-12. If no fire shows, the brake should be cooled by a straight stream of water to the exposed portion of the brake. Do this as soon as possible after the stop. Do not apply coolant directly on the wheel unless the tire is deflated. Otherwise, an explosion may result. The coolant (water) should be applied in 3- to 5-second bursts. These should be followed by a 15- to 30-second waiting period to permit dissipation of vapor pockets. Three to five applications of the coolant is usually enough. Cool the wheel in a crosswind or with a blower for at least 15 minutes before moving the aircraft.

30-13. If a fire occurs in a wheel or brake and the tire is flat, any agent can be safely used. But, if the tire has not deflated and is on fire, the possibility of an explosion exists. The wheel should be approached only from the front or rear. Water should be applied as a spray or in a dispersed pattern in short bursts for this conditions. Use only enough water to put out the fire.

31. Antiskid System

31-1. A feature found in high performance aircraft braking systems is skid control or antiskid protection. This is an important system because if a wheel goes into a skid, its braking value is greatly reduced. The purpose of a wheel brake is to bring a rapidly moving aircraft to a stop during ground roll. It does this by changing the energy of movement into heat energy through the friction developed in the brakes.

31-2. If the brake is applied so hard that the wheel locks, the process gets fouled up. A locked wheel skids and it will eventually stop the aircraft movement. But, it might take three times the normal length of the runway to do it. Have you ever tried to stop a car by locking wheel and throwing it into a skid? The car, uncontroled, skids all over the road. Aircraft act the same way if wheels lock during a roll. So, the purpose of the antiskid system is to eliminate the locking of wheels or the beginning of a lock. This will prevent skidding.

31-3. The skid control system performs four functions: (1) normal skid control, (2) locked wheel skid control, (3) touchdown protection, and (4) fail-safe protection. The main components of the system consist of two skid control generators, a skid control box, two skid control valves, a skid control switch, a warning lamp, and an electrical control harness with a connection to the squat switch.

31-4. **Normal Skid Control.** Normal skid control comes into play when wheel rotation slows down but has not come to a stop. When this slowing down happens, the wheel sliding action has just begun but has not yet reached a full scale slide. In this situation the skid control valve removes some of the hydraulic pressure to the wheel. This permits the wheel to rotate a little faster and stop its sliding. The more intense the skid is, the more braking pressure is removed. The skid detection and control of each wheel is completely independent of the others. The wheel skid intensity is measured by the amount of wheel slow-down.

31-5. *Skid control generator.* The skid control generator is the unit that measures the wheel rotational speed. It also senses any *changes* in the speed. (See fig. 121.) It is a small electrical generator (B), one for each wheel, mounted in the wheel axle. The generators armature is coupled to, and driven by, the main wheel through the drive cap (C) in the wheel. As it rotates, the generator develops a voltage and current signal. This strength of the signal indicates the wheel rotational speed. This signal is fed to the skid control box through the harness (A).

31-6. *Skid control box.* The box reads the signal from the generator and senses changes in signal strength. It can interpret these as developing skids, locked wheels, brake applications, and brake releases. It analyses all it reads, then sends appropriate signals to solenoids in the skid control valves.

31-7. *Skid control valves.* The two skid control valves (fig. 122) mounted on the brake

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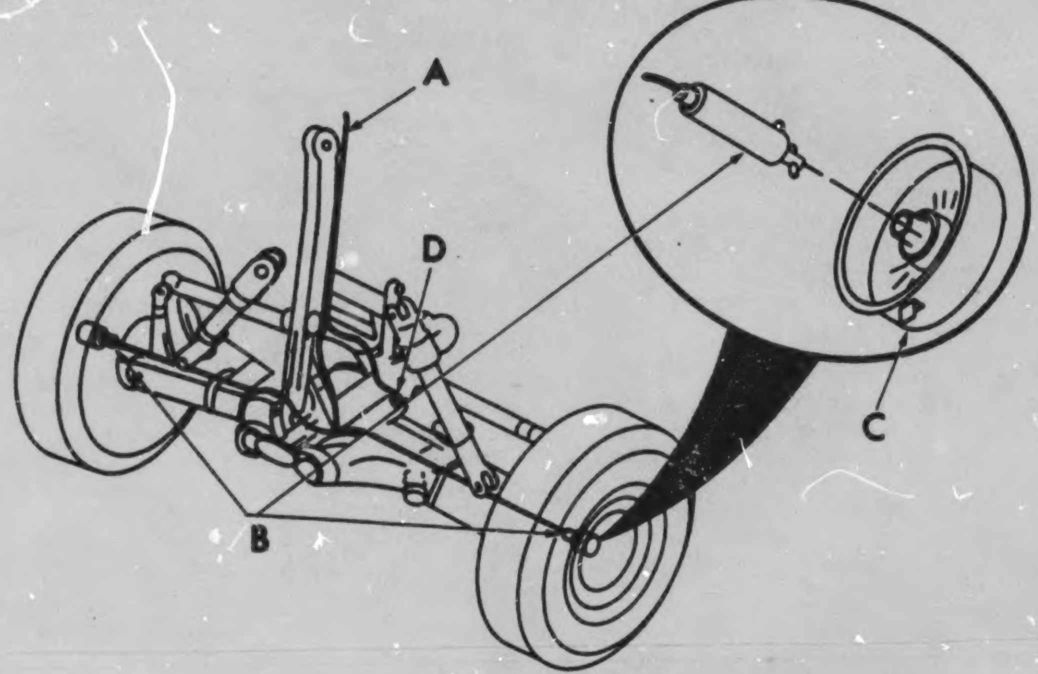

A. Electrical harness
B. Generator
C. Drive cap
D. Squat switch

Figure 121. Skid control generator.

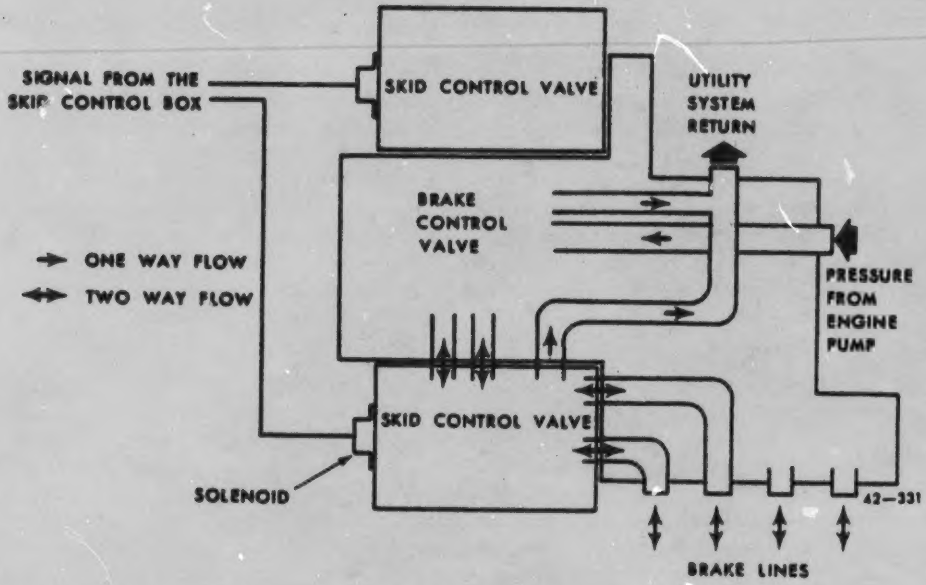
SIGNAL FROM THE SKIP CONTROL BOX
SKID CONTROL VALVE
UTILITY SYSTEM RETURN
BRAKE CONTROL VALVE
PRESSURE FROM ENGINE PUMP
→ ONE WAY FLOW
↔ TWO WAY FLOW
SKID CONTROL VALVE
SOLENOID
42—331
BRAKE LINES

Figure 122. Skid control valves.

control valve are solenoid operated. (Some skid control valves use a motorized valve.) Electric signals from the skid control box actuate the solenoids. If there is no signal (because there is no wheel skidding), the skid control valve will have no effect on brake operation. But, if a skid develops, either slight or serious, a signal is sent to the skid control valve solenoid. This solenoids' action lowers the metered pressure in the line between the metering valve and the brake cylinders. It does so by dumping fluid into the reservoir return line whenever the solenoid is energized. Naturally, this immediately relaxes the brake application. The pressure flow into the brake lines from the metering valves continues as long as the pilot depresses the brake pedals. But, the flow and pressure is rerouted to the reservoir instead of to the wheel brakes.

31-8. Figure 122 shows the utility system pressure entering the brake control valve. There it is metered to the wheel brakes in proportion to the force applied on the pilot's foot pedal. However, before it can go to the brakes, it must pass through a skid control valve. There, *if the solenoid is actuated*, a port is opened in the line between the brake control valve and the brake. This port vents the brake application pressure to the utility system return line. This reduces the brake application, and the wheel rotates faster again. The system is designed to apply enough force to operate just below the skid point. This gives the most effective braking.

31-9. The pilot can turn off the operation of the anti-skid system by a switch in the cockpit. A warning lamp lights when the system is turned off or if there is a system failure.

31-10. **Locked Wheel Skid Control.** The locked wheel skid control causes the brake to be fully released when its wheel locks. A locked wheel easily occurs on a patch of ice due to lack of tire friction with the surface. It will occur if the normal skid control does not prevent the wheel from reaching a full skid. To relieve a locked wheel skid, the pressure is bled off longer than in normal skid function. This is to give the wheel time to regain speed. The locked wheel skid control is out of action during aircraft speeds of less than 15 – 20 mph.

31-11 .**Touchdown Protection.** The touchdown protection circuit prevents the brakes from being applied during the landing approach *even if the brake pedals are depressed.* This prevents the wheels from being locked when the contact the runway. The wheels have a chance to begin rotating before they carry the full weight of the aircraft. Two conditions must exist before the skid control valves permit brake application. Without them the skid control box will not send the proper signal to the valve solenoids. The first is that the squat switch (D, fig. 121) must signal that the weight of the aircraft is on the wheels. The second is that the wheel generators sense a wheel speed of over 15 – 20 mph.

31-12. **Fail-Safe Protection.** The fail-safe protection circuit monitors operation of the skid control system. It automatically returns the brake system to full manual in case of system failure. It also turns on a warning light.

31-13. We have discussed the antiskid system used on several modern aircraft. Other aircraft use systems that are very similar in design and function, but their components operate differently. However, the components do the same jobs as we described.

31-14. You have now finished Volume 2. We hope that you have increased your knowledge of hydraulic principles and components. We wish you success in your chapter review exercise and especially in your volume review exercise. In Volume 3 you will take the principles and components you have already mastered and tie them together into systems.

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STUDY REFERENCE GUIDE

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201 Hydraulic Terms and Laws; pages 3–4

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CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

CHAPTER 1

Objectives: To demonstrate knowledge and understanding of pneumatic principles and arrangement of basic systems.

1. Explain the difference between a liquid and gas. (1-1)

2. Why are liquids a suitable medium for transmitting force? (1-2, 4)

3. Why is pressure transfer in a hydraulic system instantaneous? (1-2)

4. Why is it necessary to have an air space in hydraulic reservoirs? (1-3)

5. Explain why the viscosity of a liquid is critical in a hydraulic system. (2-3)

6. Explain the term "critical velocity." (2-4)

7. What are the two types of fluid flow? (2-4)

8. Why is there a decrease of pressure at the narrowest part of a venturi? (2-7–9)

9. What is the difference between *force* and *pressure*, as applied to hydraulics? (3-4, 5)

10. State Pascal's law. (3-11)

11. Under what condition does Pascal's law *not* apply? (3-11)

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12. What is the pressure on a surface 12 square inches in area that is supporting a weight of 216 pounds? (4-2–4)

13. How far must an 8 square inch piston move to displace 120 cubic inches of fluid? (4-5)

14. Define mechanical advantage. (5-1)

15. In the system shown in figure 12, the small piston moves five times as far as the large piston; the area of the large piston is 12 inches, and the fluid pressure is 60 psi. Complete the following chart. (5-5; Fig. 12)

	Small Piston	Large Piston
Force =	____________	____________
Pressure =	____________	____________
Area =	____________	____________
Mech. Advantage =	____________	

16. If a force of 25 pounds is applied, what is the mechanical advantage needed to achieve a force of 600 pounds? (6-2–4)

17. What do the terms "up lines" and "down lines" in a hydraulic system refer to? (7-2)

18. When the relief valve opens, what is the effect on the power pump, as compared to the effect on the pump when the pressure regulator opens? (7-5; 9-12)

19. Referring to figure 17, what will be the "kick-out" pressure if the spring tension is changed to 900 pounds? (7-9, 10; Fig. 17)

20. When the pressure regulator is "kicked out," is it open or closed? (7-7, 15)

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21. When the power pump is idling, is check valve K in figure 19 open or closed? (7-11; Fig. 19)

22. What would be the probable cause of excessive operating pressure in the system shown in figure 19? (7-12; Fig. 19)

23. What hydraulic unit acts as a shock absorber for sudden hydraulic pressure surges? (7-15)

24. How does the accumulator prevent the pressure regulator from operating excessively? (7-16–18)

25. What is the function of check valve M in figure 19? (7-25; Fig. 19)

26. What unit insures a positive fluid supply for the hand pump? (7-26)

27. Why is it necessary to synchronize action in hydraulic systems? (7-27)

CHAPTER 2

Objectives: To demonstrate a working knowledge of the construction and operation of hydraulic fluid reservoirs, filters, hand and common types of power pumps.

1. What level of maintenance is the everyday servicing and upkeep of aircraft hydraulic systems? (Intro.-2)

2. What is the function of the hydraulic reservoir? (8-1)

3. If the reservoir filter element becomes clogged, how does it affect system operation? (8-4)

4. What three features are included on the reservoir to insure that a clean and adequate supply of hydraulic fluid is available? (8-4)

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5. Why is there a standpipe in a hydraulic reservoir? (8-5)

6. What are the functions of the accumulator installed in a hydraulic system? (8-9)

7. Explain the purpose of the initial air charge of an accumulator. (8-9)

8. How do you determine when the reservoir of a piston-pressurized reservoir system needs servicing? (8-11)

9. What component will drain or bleed the piston-pressurized reservoir? (8-17)

10. Why do we pressurize a hydraulic reservoir? (8-18)

11. How does the suction boost pump pressurize the hydraulic reservoir? (8-21)

12. Where can the mechanic find the instructions for servicing a hydraulic system reservoir? (8-25)

13. Before you start to remove a reservoir, what is one of the first things you should do? (8-26)

14. What is the deadliest enemy of any hydraulic system? (9-1)

15. What is the most common type of hydraulic filter element? (9-2,3)

16. Why is a relief valve installed in a line filter? (9-3)

17. What would happen if an in-line filter restrictor finger strainer becomes clogged? (9-4)

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18. What should be done when you find a clogged filter assembly? (9-6)

19. What is the purpose of a line-disconnect valve? (9-7)

20. The poppet in a line-disconnect is malfunctioning. What should the mechanic do? (9-11)

21. Why are hand pumps used in a hydraulic systems in addition to the power pumps? (10-2)

22. On what stroke does the double-acting, piston-displacement-type hand pump produce pressure? (10-3)

23. What is the function of the check valve in the pressure outlet side of the piston-displacement-type hand pump? (10-3, 5)

24. A hand pump with a normal working pressure of 750 psi is overhauled. At what pressures would you perform proof pressure and leakage checks? (10-8, 9)

25. What is the most common of main system hydraulic pumps in use today? (10-11)

26. What determines the volume output of a constant-volume piston-type pump? (10-14)

27. What is case pressure in a piston-type pump? How is it used? (10-18)

28. What is the function of a foot valve in power pumps? (10-18, 32)

29. List the advantages of a variable-volume over a constant-volume pump. (10-21)

30. In the zero flow condition of the Stratopower pump, is there any fluid intake? (10-26)

31. What must be done to a Stratopower pump in order to change its direction of rotation? (10-27)

32. In the Vickers variable-volume pump, how is the volume output of the pump reduced to zero flow when the maximum pressure setting of the system is reached? (10-29–33)

33. How is the rpm of the variable-displacement hydraulic motor controlled? (11-2)

34. What is the function of the back pressure valve used in the variable-displacement hydraulic motor? (11-6)

CHAPTER 3

Objectives: To show a working knowledge of the types of switches, pressure regulators, relief valves, purge valves, accumulators, and pressure-reducing valves used to regulate the pressure of fluid output of hydraulic pumps.

1. If the electric driven hydraulic pump shuts *off* before the desired system pressure is reached, what is a probable cause? (12-1)

2. List the three main types of pressure switches in use today. (12-1)

3. Why does the Bourdon tube try to straighten when pressure is introduced? (12-2)

4. How is burning of the contact points reduced on the pressure switch? (12-7)

5. What are the purposes of pressure regulators? (12-9)

6. Must an accumulator be used in a system having a constant-volume pump? Why? (12-9)

7. When the hydraulic main pump is *loaded*, in what status is the regulator? (12-10)

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8. What controls the check valve in a pressure regulator? (12-11, 12)

9. What are the two types of pressure regulators? (12-15)

10. What symptom predicts a leaking pressure regulator check valve? A leaking bypass valve. (12-21–23)

11. Can the kick-out pressure of the regulator be changed? How? (12-22)

12. What is the most obvious difference between the diaphragm and bladder types of accumulators? (13-3, 6)

13. What is meant by air preload pressure of an accumulator? (13-4, 5)

14. What insures that there is adequate cylinder wall and piston lubrication in a piston-type accumulator? (13-7)

15. The self-displacing type accumulator is used primarily on what aircraft? Why? (13-8)

16. Before you start to disassemble any accumulator, what must be done? (13-14)

17. Leakage and proof pressure tests of bladder and diaphragm accumulators require the use of test stand with what capabilities? (13-16)

18. Following overhaul of accumulators, you must perform certain checks. What check do you do on a piston type accumulator that you don't do on a diaphragm type? (13-19)

19. Why doesn't the system relief valve unload the power pump? (14-2)

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20. What is the difference in construction between a system relief valve and a thermal relief valve? (14-3, 4)

21. To increase the pressure setting at which a relief valve relieves, you normally turn the adjusting screw in which direction? (14-5, 17)

22. Briefly explain what is meant by the *cracking pressure* of a relief valve. (14-11)

23. Approximately to what percent above cracking pressure is full flow pressure? (14-11)

24. Why do we have purge valves? (14-19, 21)

CHAPTER 4

Objectives: To show a knowledge of selector valves, orifices, check valves, snubbers, sequence and shuttle valves, hydraulic flow regulators, equalizers, fuses, and actuators.

1. For what purpose are selector valves in a hydraulic system? (15-1)

2. How are closed-center-type selector valves usually installed in a system? (15-2)

3. The actuator cylinder has one pressure line and a spring to return it to neutral. What type of selector valve would you expect to find in use with this type of actuator? (15-4)

4. When the four-way selector valve is in the neutral position, what happens to relieve thermal pressure in the alternating lines? (15-7)

5. In the radial selector valves, what are the maximum number of ports that can be open at any one time and the maximum number of ports that can be closed at any one time? (15-10, 11)

6. Referring to a poppet-type radial selector valve, what happens if you adjust the screws too far clockwise? (15-12)

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7. What are the advantages in using compound selector valves? (15-13)

8. Why would a slide-type selector valve be used in a boost system in preference to a poppet-type valve? (15-14)

9. Why is a variable-restrictor control valve used in an open-center boost system in preference to a rotor-type, open-center selector valve? (15-21)

10. In a system using the variable-restrictor control valve for flight controls operation, what determines the travel of the flight controls? (15-24)

11. What are the advantages of electrically operated selector valves? (15-25)

12. What is the difference in the operation of a check valve and an orifice? (16-2, 3)

13. A variable orifice valve used in a hydraulic system is frequently referred to as what type valve? (16-4)

14. Why would an orifice check valve be used in a landing gear system? (16-8)

15. What is the last step when installing a snubber in a pressure gage line? (16-11)

16. What is the purpose of a shuttle valve? (16-12)

17. What unit insures a constant rate of flow to an actuator regardless of its load? (16-15)

18. How are hydraulic flow regulators rated? (16-19)

19. What unit can divide one stream of fluid into two equal streams? (16-20)

20. Why do we need a fuse in a hydraulic system? (16-28)

21. What determines the quantity of fluid that can flow through a hydraulic fuse? (16-31)

22. How long will it take for a hydraulic fuse to "fuse" after a leak develops? (16-34)

23. What very important procedure must you observe when you reassemble control valves using two or more identical parts? (16-35)

24. What is the purpose of a hydraulic actuator? (17-1)

25. What force moves a double-acting actuator to its opposite extreme of travel? (17-2)

26. What type of a hydraulic actuator provides more force in one direction than in the other? (17-5)

27. What is the function of an internal snubber-type actuator? (17-9)

28. How do we unlock the internal lock-type actuator? (17-17)

CHAPTER 5

Objectives: To demonstrate a knowledge of landing gear components such as air-oil shock struts, liquid spring shock struts, shimmy dampers, and steering damper units.

1. What is the most common type of shock strut in use today? (18-1)

2. Explain how rotation of the piston within its cylinder on shock struts is prevented. (18-2)

3. On what does the proper shock absorbing operation of an air-oil shock strut depend? (18-4)

4. What unit in some air-oil shock struts automatically controls the area of the orifice at all points in the stroke of the strut? (18-7)

5. At which point in its stroke must an air-oil shock strut be when it is serviced with fluid? (18-9)

6. If you loosen the valve body of the high-pressure air valve on a shock strut before the pressure has been removed, what can happen? (18-13)

7. Explain the difference between hard and soft strut servicing. (18-15–17)

8. What is the main advantage of a soft strut over a hard strut? (18-17)

9. Why should you rock the aircraft wings while servicing the air-oil type shock strut? (18-18)

10. What defects other than faulty hydraulic seals would cause a shock strut to leak? (18-21)

11. Shock strut parts are cleaned by dipping in a solution. How is this solution removed from the parts? (18-25)

12. What paint is used for corrosion treatment of the external surfaces of repaired shock struts? (18-29)

13. What is MIL–H–6083A fluid used for? (18-31)

14. Explain the operation of the liquid spring strut. (18-35–37)

15. What type of hydraulic fluid is used in a liquid spring strut? (18-39)

16. At what point in its stroke must a liquid spring strut be when servicing with liquid? (18-42)

17. What is the function of a shimmy damper? (19-1, 2)

18. Define the characteristic of a shimmy damper that causes little resistance to slow movement while steering but offers a great resistance to violent motions due to shimmy. (19-3, 11, 14)

19. What is used to replenish the hydraulic fluid in the vane-type shimmy damper and why? (19-6)

20. What might prevent a nose wheel equipped with a vane-type shimmy damper from tracking properly? (19-6)

21. What could be wrong internally if a vane-type nose wheel shimmy damper did not prevent shimmy? (19-6)

22. What could happen if you install an orifice instead of an orifice-check valve in a balanced-piston-type shimmy damper? (19-11)

23. What characteristic of a balanced-piston-type shimmy damper would make it desirable for use as a steering unit? (19-11)

24. How do co-rotating wheels tend to prevent nose wheel shimmy? (19-16)

25. What is the disadvantage of co-rotating nose wheels? (19-17)

26. What is the reason for the self centering device on a nose gear? (20-2)

27. Where does the vane-type steering damper unit get its hydraulic pressure to operate nose wheel steering? (20-12)

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CHAPTER 6

Objectives: To be able to identify and show a working knowledge of the three main types of brake systems used on all aircraft: the independent, integral, and slave brake systems, and of deboosters and antiskid controls.

1. In an independent brake system, what unit changes the pilot's force to hydraulic pressure? (21-2)

2. If main system pressure were lost in a system using a brake boost cylinder, would the pilot be able to apply any braking action? (21-3)

3. What are two advantages of a slave brake system? (21-5)

4. In addition to the normal pressure produced in a braking system, what else will cause pressures to build up? (21-6)

5. What provides pressure in an independent brake system? (22-1)

6. What is done to unlock the parking action of the independent brake system? (22-4, 9)

7. Briefly explain the operation of a master cylinder operated pneumatic brake system. (22-11)

8. What are some ways by which air may enter a brake line? (22-14)

9. Explain the two methods used to bleed an independent brake system. (22-16–18)

10. If you find a brake that has more than one bleeder valve, how do you bleed this brake? (22-19)

11. Why do we have "load feel" in a brake system? (23-2)

12. In a PBCV operated system, what controls the actual amount of braking action? (23-10)

13. On a power brake control valve, what is the purpose of the high-pressure adjustment? (23-15)

14. What are some of the advantages of a slave brake system? (23-22)

15. What should always be done before taxiing an aircraft? (24-1)

16. What do you use to perform the proof pressure and external leakage check on a reassembled brake valve? (24-5)

17. How does a debooster insure rapid application of the brakes? (25-1)

18. With an automatic replenishing debooster, what unit or units provide for replenishing the fluid content? (25-7)

19. If a debooster is not replenished automatically, what provision is made for manual replenishing? (25-8)

20. What factors determine the amount of kinetic energy contained in a moving object? (26-2)

21. What is the main disadvantage of the multiple disc-type brake? (26-10)

22. How is the running (off) clearance of a multiple disc brake measured? (26-15)

23. What type of brake assembly may be relined while on the aircraft? (27-5)

24. What would be the effect if the diaphragm seat of the expander tube brake adjuster valve were held open because of a dirty seat? (27-8, 9)

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25. To what are the linings used in the segmented rotor brake attached? (28-1)

26. How will the amount of wear authorized by the TO on segmented rotor brakes be determined? (28-7)

27. What is an advantage of the spot disc-type brake over the multiple disc brake? (29-6)

28. What is the effect of overtorquing the adjusting nut (B) of figure 119? (29-11; Fig. 119)

29. When is the running clearance of single and dual disc brakes adjusted? (29-13)

30. In the repair and surface treatment of brake assemblies, why smooth out sharp edges and indentations? How? (30-6)

31. If a take-off is aborted, what should be done? (30-11)

32. Why should you never direct a stream of cold water directly on the tires of an aircraft that has undergone extreme braking? (30-12)

33. What are the functions of a skid control system? (31-3)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

1. A liquid flows but will not expand indefinitely to fill a container; while a gas, which also flows, expands to fill the container. A liquid has a definite and level top surface.

2. They are practically incompressible and will transmit the same amount of pressure equally in all directions.

3. Because, for all practical purposes, hydraulic fluid is incompressible.

4. Because fluids expand, they could cause enough pressure to burst a reservoir.

5. Viscosity is the characteristic of a liquid that makes it resist flowing. The higher the viscosity, the higher the resistance.

6. Critical velocity is the speed of the liquid flow where the entire tube cross section becomes turbulent and the total flow velocity drops. These conditions will cause the total flow quantity to drop.

7. Laminar and turbulent.

8. The narrow section of the venturi causes the velocity of the fluid to increase which, in turn, causes the pressure to decrease.

9. Force is a push or pull exerted on an object, measured in pounds. Pressure is the amount of force per unit of area.

10. When force is exerted on a confined fluid, the pressure is transmitted equally and undiminished in all directions.

11. When the fluid is in motion.

12. P equals F/A, or 216 pounds divided by 12 square inches equals 18 psi.

13. 15 inches.

14. The amount by which the input effort is multiplied in the output device.

15. F = 144 lbs
    P = 60 psi
    A = 2 2/5 sq in
    MA = 5 to 1

    F = 720 lbs
    P = 60 psi
    A = 12 sq in

16. 24 to 1.

17. Those alternating lines between the selector valve and actuating cylinder which supply pressure to move the mechanism up or down.

18. When the relief valve opens, the pump still carries the maximum load. Using a pressure regulator, the pump load is relieved.

19. Greater than 1200 psi.

20. Open, with fluid returning to the reservoir.

21. Closed.

22. Pressure regulator failure.

23. The accumulator.

24. By preventing rapid pressure drop in the system due to minor leakage.

25. To prevent charging the accumulator when using the hand pump.

26. The reservoir standpipe that supplies the power pump and reserves the fluid below its top for the hand pump.

27. Most systems have actuators connected in parallel; therefore, without synchronization the unit requiring the lowest pressure would operate first, and might move to the end of its travel before the next unit began to move. In *some* systems we must have a set sequence of operation.

CHAPTER 2

1. Organizational.

2. It is the storehouse that contains enough fluid to supply the normal operating needs of the system.

3. System operation is not affected, because the unfiltered fluid is bypassed through a relief valve.

4. *a.* A visual quantity indicator.
   b. A screen on the filler line.
   c. A filter on the return port of the reservoir.

5. To keep the main system pump from pumping the reservoir completely dry if a leak develops. There should be enough left in the reservoir for emergency operations.

6. The accumulator dampens pressure surges, aids the power pump at peak loads, and prevents rapid cycling of the pressure regulator.

7. The initial air charge provides a cushioning effect, keeps the pressure regulator from cycling due to minor fluid leakage, and permits the storage of a volume of fluid, under pressure, in the accumulator.

8. The indicator pin position tells the level of fluid in the reservoir. When its end is flush with the housing, the system needs fluid.

9. The relief valve that opens into the overboard vent line.

10. Cavitation of the main system pump could develop, and starvation of the hydraulic system would result. Pressurization also aids in controlling foaming of the hydraulic fluid.

11. No. Instead, it supplies a large volume of liquid under lower pressure to the main pump. This prevents main pump cavitation.

12. Special instructions are normally located on a data plate attached to the reservoir. Additional or more complete instructions can be found in the applicable technical order.

13. The pressure should be completely removed from the system. This should be double checked before any lines are disconnected.

14. Dirty fluid.

15. Micronic.

16. If the filter element should become clogged, the relief valve will open and allow fluid to bypass the clogged element.

17. Since there is no relief or bypass valve used with these, the subsystem in which they are located would become inoperative.

18. You should clean or replace the clogged filter element. After this, the fluid and the system should be inspected for possible contamination and, if need be, flushed.

19. Line disconnects allow quick removal and installation of a unit without loss of fluid.

20. The mechanic should remove and replace the complete assembly. No internal repairs are authorized.

21. Hand pumps are used to operate the system for ground test and for emergency operation of units.

22. It produces pressure on both strokes.

23. The outlet check valve insures ejection of fluid on at least one stroke in case one of the other pump check valves fails.

24. Proof pressure is 1½ times operating pressure; in this case it would be 1125 psi. The leakage check pressure is the normal operating pressures; in this case it would be 750 psi.

25. A piston type.

26. The angle between the drive shaft and the cylinder block. The higher the angle, the more the volume.

27. Case pressure results from internal seepage into the gear housing. This provides cooling and lubrication for the pump.

28. A foot valve in a power pump relieves excess case pressure back to the return port.

29. *a.* It does not need a pressure regulator or unloading valve.
    b. It provides a more constant pressure.
    c. The accumulator can function to assist the pump during peak periods, and the pressure is not subject to as many fluctuations.

30. Fluid is drawn into the pump for cooling and lubrication and is then circulated through the out port.

31. Nothing. Changes are unnecessary.

32. Zero flow is obtained by the cylinder block and piston assembly being moved to a zero angle in relation to the drive shaft.

33. By a very sensitive, flyweight-operated governor.

34. It keeps a pressure on the backside of the lower pistons. This holds them against the wobbler plate and thereby prevents them from chattering.

CHAPTER 3

1. An improperly adjusted pressure switch.

2. Bourdon, piston, and diaphragm.

3. The area upon which the pressure can act outward is greater than the area upon which the pressure can act inward.

4. The overcentering spring causes the toggle plate to open and close the points rapidly.

5. To unload the engine-driven pump and regulate system pressure between two limits.

6. Yes. To prevent continual cycling of the pressure regulator.

7. The regulator is kicked in.

8. The bypass valve.

9. Balanced and selective.

10. A leaking check valve causes an early kick-in, and a leaking bypass valve causes a late kick-out.

11. Yes, by turning an adjustment screw while the regulator is on the aircraft.

12. The diaphragm consists of two hollow half ball sections joined at the center while the bladder type is one piece with an opening for inserting the bladder.

13. This is the air pressure that is charged into the accumulator while the accumulator is completely empty of any hydraulic fluid.

14. There is a drilled passage from the fluid side of the accumulator to the space between the two seals of the piston.

15. It is used primarily on combat aircraft. These aircraft are highly maneuverable and operate at high speeds and demand immediate response to the controls. This type of accumulator will provide them with this response.

16. You should always make certain that all pressures have been relieved, both hydraulic and air.

17. A stand that can provide a controlled hydraulic pressure of up to 5000 psi and an air pressure of at least 1000 psi.

18. Friction test the piston type accumulator to determine the actual pressure required to move the piston.

19. The pump must still deliver fluid against maximum system pressure to hold the relief valve open.

20. The thermal relief valve is smaller.

21. In a clockwise direction.

22. The cracking pressure of a relief valve is the pressure at which the ball is slightly unseated, allowing a few drops of fluid to be relieved.

23. 10 percent.

24. These valves release air that may be in the pressure lines. They also act as unloading valves for electric and turbine-driven emergency pumps so they will not have to start under a load that might cause a burn-out.

CHAPTER 4

1. To control the directional movement of various mechanisms.

2. They are placed in parallel between the pressure and return manifolds.

3. A three-way selector valve.

4. The excessive pressure trapped in the lines will lift the upper poppet valve and relieve into the system pressure manifold.

5. You can have two poppets open at any one time; by rotating the handle 45° more, you can close all four of the ports.

6. It would prevent the poppets from being off-seated soon enough and far enough. This would cause a delay in the start of operation and a decrease in the volume of fluid flow, which in turn would result in slower operation of the actuated component.

7. They conserve space and simplify installation.

8. Slide-type selector valves can *meter* varying quantities of fluid, while poppet-type selector valves are not capable of metering fluid.

9. Variable-restrictor control valves can meter varying amount of fluid and pressure, thereby giving a smoother and more positive control.

10. The airload opposing their movement and the hydraulic pressure applied to the actuator.

11. *a.* Removal of high pressure lines from the cockpit.
    b. Weight saving.
    c. Can be used to remotely position mechanical units.

12. A check valve allows fluid to flow in one direction and no flow in the other. An orifice is a restrictor and limits the rate of flow but will allow it to go in either direction.

13. It is referred to as a *globe* or *star valve.*

14. To retard the speed of actuator operation in one direction only.

15. Bleed the air out of the gage line.

16. To separate the normal system from the emergency system.

17. Flow regulator.

18. By their capacity or how many gallons per minute of fluid flow they will allow.

19. Flow equalizer.

20. If a leak develops, the fuse will shut off the flow in that section before the complete hydraulic supply has been lost.

21. The orifice.

22. The fuse will allow slightly more than the quantity of fluid to flow that is normally required to operate the component. When this quantity has been passed, the fuse will close.

23. The same parts must be reinstalled in the same cylinder, sleeve, or housing. This is imperative because their identical parts are mated (machined) to their respective retainer.

24. To transform fluid pressure into a mechanical force.

25. Hydraulic fluid under pressure applied to the other side of the piston and forcing it to move.

26. A double-acting unbalanced actuator.

27. It prevents the actuator from slamming into the extremes of travel and will thereby prevent damage.

28. By applying hydraulic pressure to the proper port.

CHAPTER 5

1. The air-oil strut.

2. Rotation is prevented by the torque arms, or scissors.

3. The proper preload of air as well as the resistance to movement caused by the hydraulic fluid moving through some type of restriction.

4. The metering pin.

5. Completely compressed.

6. The whole valve assembly can be blown off resulting in injury to people and damage to equipment.

7. In hard servicing you fill the strut with fluid to the inlet plug level and then apply air pressure until the strut reaches its proper extension length. Soft servicing requires that the strut be filled to the plug level, air applied to a predetermined pressure, and then additional fluid added under high pressure until the strut is extended.

8. A soft strut prevents metal to metal contact of strut during hard landings.

9. To eliminate any binding of the shock strut, thereby making certain you get the proper inflation and proper extension.

10. Nicks, burrs, scratches, or cracks on the shock strut piston.

11. The parts are dipped or rinsed in cold water, then dipped in hot water for from 2 to 4 minutes.

12. Two coats of zinc chromate primer and then two coats of aluminum lacquer.

13. It is used to fill a repaired shock strut internally before it is stored away. It is a preservative.

14. It operates on the principle that at extremely high pressures liquids are in fact compressible.

15. A silicone base hydraulic fluid which is exotic and expensive.

16. Fully extended.

17. To prevent oscillations of the nosewheel during landing, takeoff, and taxiing.

18. The tendency of the orifice to increase its resistance to fluid flow with an increase of force and velocity.

19. You must use a pressure gun to add fluid as an internal piston keeps the reservoir under pressure at all times.

20. A plugged orifice.

21. Too large an orifice.

22. It could cause a partial vacuum to be formed when rapid movement is experienced and the shimmy action would be spongy.

23. The equal areas on both sides of the piston will provide equal forces in either direction.

24. The wheels are on a common shaft and to shimmy, one wheel must move forward, thereby causing the other wheel to skid or slip. There is a natural tendency to resist this.

25. Increased tire wear results.

26. To make certain that the nose gear is streamlined for retraction.

27. Fluid under pressure is supplied by the normal aircraft hydraulic system.

CHAPTER 6

1. The master cylinder.

2. Yes. It will still act as a master cylinder, and the pilot can supply the force.

3. It reduces weight by using less tubing and eliminates high-pressure lines in the cockpit (this decreases the fire hazard).

4. By thermal expansion of the fluid.

5. The master cylinder.

6. Push firmly on the brake pedals to release the ratchet action.

7. Hydraulic pressure from the master cylinder directs hydraulic fluid to the air relay (metering) valve which in turn directs compressed air to the brake for braking action.

8. Disconnecting a line or unit, low supply in the reservoir, or a leak.

9. The gravity system is used. In one operation the bleed valve is left open while pumping the master cylinder up and down until all air is removed. In the other method the bleed valve is open while the master cylinder is depressed and closed when the pedal is raised. This is repeated until all air is removed.

10. You go through the normal bleeding sequence for each of the bleeder valves.

11. This makes the pilot aware of the amount of braking action he is applying.

12. The force applied to the brake pedal which determines the upward movement of the piston.

13. To adjust the maximum amount of pressure the valve will deliver.

14. There is a weight saving; also, there are no high-pressure hydraulic lines in the cockpit.

15. Check the brakes for operation.

16. Use a hydraulic test stand such as the HCT-6.

17. It is used on large aircraft to greatly increase the volume coming from the power brake valve and lower the pressure.

18. The compensating valve and opening pin.

19. An external bypass line with a star valve is used to manually replenish the debooster.

20. The mass (weight) of the object and its velocity (speed).

21. Warping of the discs because of overheating.

22. By two feeler gages opposite each other between the retaining nut and adjoining steel disc.

23. The type of expander tube brakes with stamped frames.

24. The brakes' OFF clearance would be at a maximum.

25. They are riveted to the stationary disc.

26. By measuring the amount of adjuster pin still showing on the outside of the friction clamp.

27. Better cooling.

28. Friction on the pin will be too great; thus, hydraulic pressure may not be able to move the pin inward to compensate for lining wear.

29. When new linings are installed.

30. Because they are areas of stress concentration. This is done using a smooth-cut file and emery cloth.

31. Call the fire department and evacuate the area for 300 feet on both sides of the brakes as they brakes may ignite and the tires explode.

32. Because the tire might explode.

33. *a.* Normal skid control.
    b. Locked wheel skid control.
    c. Touchdown protection.
    d. Fail safe protection.

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STOP– **1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.** **2. USE NUMBER 1 PENCIL.**

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VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Use a clean eraser for any answer sheet changes, keeping erasures to a minimum.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

Multiple Choice

Chapter 1

1. (200) A liquid under pressure is an effective means of moving aircraft mechanisms because of its

   a. compressibility.
   b. viscosity characteristics.
   c. relative incompressibility.
   d. resistance to temperature changes.

2. (200) One advantage of using liquid for transmitting power is the

   a. high compressibility factor of liquid.
   b. low thermal expansion factor of the liquid.
   c. ability of the liquid to transfer pressure equally in all directions.
   d. negligible shearing action that exists between the wall of the tube and the liquid.

3. (200) What are the two types of fluid flow?

   a. Smooth and turbulent.
   b. Laminar and turbulent.
   c. Uniform and turbulent.
   d. Streamlined and turbulent.

4. (200) When liquid flows through a venturi, the pressure will be

   a. the same throughout the venturi.
   b. least at the throat of the venturi.
   c. unaffected as the velocity decreases.
   d. greatest at the throat of the venturi.

5. (201) Force in a hydraulic system is determined by the amount of

   a. fluid available.
   b. volume from the pump.
   c. distance an object is moved.
   d. push or pull on an object.

6. (201) When heat is applied to a confined fluid,

   a. the pressure will increase.
   b. the flow will be more restricted.
   c. viscosity change will slow its velocity.
   d. it will cause a greater amount of turbulence.

7. (201) A master cylinder is connected to four actuating cylinders having cross-sectional areas of 1 square inch, 2 square inches, 3 square inches, and 4 square inches, respectively. If the piston in the master cylinder developed 100 psi, the pressure on each of the four stabilized pistons in the cylinders would be

   a. 25 psi.
   b. 100 psi.
   c. 10 psi, 20 psi, 30 psi, and 40 psi, respectively.
   d. 100 psi, 200 psi, 300 psi, and 400 psi, respectively.

8. **(202) To find the *pressure* applied to a hydraulic actuator when the area and force are known, you would**

a. divide force by area.
b. add force and area.
c. multiply force by area.
d. subtract force from area.

9. (202) If a force of 100 pounds is applied to a cylinder piston having an area of 2 square inches and the resultant pressure is transmitted to another cylinder piston having an area of 4 square inches, what will be the resultant force on the second piston?

a. 100 pounds.
b. 200 pounds.
c. 400 pounds.
d. 800 pounds.

10. (202) The piston within a master cylinder has an area of ¼ square inch and moves 16 inches. The piston within the actuating cylinder has an area of 4 square inches and will move

a. 1 inch.
b. 2 inches.
c. 4 inches.
c. 1/16 inch.

11. (202) A piston has an area of 4 square inches and is moved by a force of 100 psi pressure. How much volume is required to move the piston 10 inches?

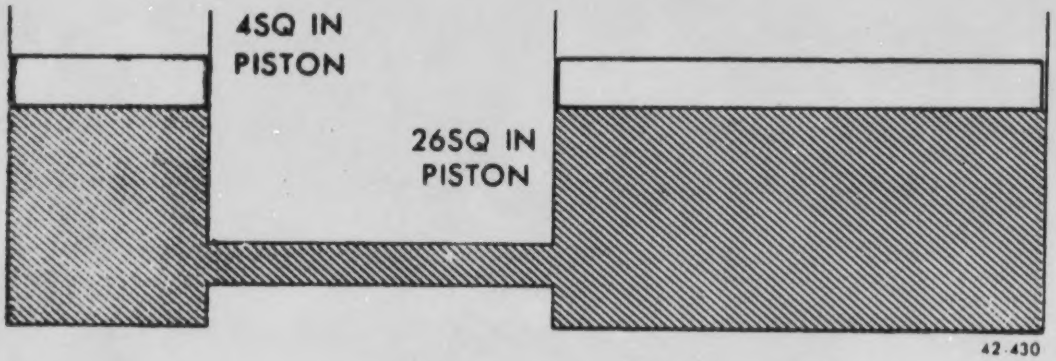
a. 2.5 cubic inches.
b. 25 cubic inches.
c. 40 cubic inches.
d. 400 cubic inches.

12. (202) Two pistons are connected by a piece of tubing; one piston has an area of 2 square inches and the second has an area of 4 square inches. How many inches would the large piston move and how much force would be required to move the 2-square-inch piston 10 inches if the large piston piston has 200 psi of pressure applied to it?

a. 6 inches–50 pounds.
b. 8 inches–50 pounds.
c. 5 inches–800 pounds.
d. 15 inches–800 pounds.

13. (203) If the smaller piston in VRE figure 1 has a 360-pound force applied to it, the larger piston will exert an upward force of

a. 2340 pounds.
b. 3340 pounds.
c. 4340 pounds.
d. 5340 pounds.



Volume Review Exercise Figure 1.

14. (203) When a 50-pound force will balance a 250-pound weight, a mechanical advantage has been achieved. This is expressed as a ratio of

a. 1:5
b. 5:1.
c. 50:250.
d. 250:50.

15. (203) A hydraulic jack has two cylinders. The pump cylinder piston has an area of 2 square inches and the jack piston has an area of 8 square inches. How many 4-inch strokes will be necessary to raise the jack 12 inches?

a. 8.
b. 12.
c. 24.
d. 32.

16. (204) The volume of a cylinder 5 inches high (length) with a 1-inch radius is

a. 1.57 cubic inches.
b. 3.14 cubic inches.
c. 15.7 cubic inches.
d. 31.4 cubic inches.

17. (205) A simple four-port selector valve is *best* described as having

a. 1 pressure, 1 return, 1 up, and 1 down port.
b. 2 return, 1 pressure, and 1 alternating port.
c. 2 pressure, 1 return, and 1 alternating port.
d. 2 alternating, 1 pressure, and 1 return port.

18. (205) Which of the following is the probably cause if a pressure regulator kicks in and kicks out at a very rapid rate?

a. A relief valve is set too low.
b. There is a leak in the pressure line downstream of the regulator.
c. The regulator check valve is stuck closed.
d. The accumulator diaphragm is ruptured.

19. (205) What is the purpose of a standpipe in a reservoir?

a. To protect the pump.
b. To supply the pump during inverted flight.
c. To reserve fluid for the power pump.
d. To reserve fluid for the hand pump.

Chapter 2

20. (206) If a hydraulic reservoir is pressurized to 25 psi, how much pressure would be in the return line to the reservoir?

a. 24 psi.
b. 25 psi.
c. 27 psi.
d. 50 psi.

21. (206) If a hydraulic reservoir is an airless type, what are the methods of pressurizing it?

   a. Venturi tee and jet pump.
   b. Spring tension and jet pump.
   c. Hydraulic pressure and venturi tee.
   d. Hydraulic pressure and spring tension.

22. (207) Line-disconnects or quick-disconnects are used in pneudraulic systems to

   a. allow for bleeding of the system.
   b. prevent the loss of pressure when a unit is removed.
   c. prevent the loss of fluid when a unit is removed.
   d. prevent any fluid loss in the event of a broken line.

23. (208) During overhaul of a hydraulic hand pump, what parts are always replaced?

   a. All cure dated parts.
   b. The threaded fittings.
   c. The needle valves and seats.
   d. All ball check valves and springs.

24. (208) What is used to prevent damage to the engine if an engine-driven hydraulic pump should freeze?

   a. A slip clutch.
   b. A pressure regulator.
   c. A pump drive shaft shear section.
   d. A variable-restrictor control valve.

25. (208) Case pressure in a pump insures

   a. that the pump is primed.
   b. pump lubrication and cooling.
   c. that the bushings fit snugly against the gears.
   d. pump lubrication and prevents air from entering the pump.

26. (208) If a new constant-volume, piston type pump with two foot valves is drawn from supply and indicates the wrong direction of rotation, you must

   a. rotate the valve plate head 180° only.
   b. install an accessory drive of correct rotation.
   c. reverse the suction and pressure connections only.
   d. rotate the valve plate head 180° and reverse the suction and pressure connections.

27. (208) Fluid output of the Vickers variable-displacement pump is determined by the

   a. rpm of the drive shaft.
   b. position of the pilot valve.
   c. spring tension on the internal relief valve.
   d. angle between the drive shaft and the cylinder block.

28. (208) In hydraulic pumps in which the pistons reciprocate in a rotating cylinder barrel,

   a. alternate pistons suck in and expell fluid.
   b. all pistons suck in or expell fluid at the same time.
   c. pistons suck in and expell fluid every other revolution of the cylinder barrel.
   d. the pistons on one side of the barrel suck in fluid, while the pistons on the other side are expelling.

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29. (209) In the hydraulic drive motor, the angle of the wobbler plate determines the

a. flyweight rotation.
b. tension of the governor spring.
c. amount of movement of the pistons.
d. venting of the control piston to the system return line.

30. (209) Which component in the hydraulic drive motor prevents overtravel of the governor control valve when the motor tends to overspeed?

a. Preact piston.
b. Control piston.
c. Governor spring.
d. Back pressure valve.

Chapter 3

31. (210) We use the Bourdon tube type pressure switch in the main aircraft hydraulic system because

a. it is a rugged piece of equipment.
b. there is never any adjustments required.
c. this is the only method of turning the pump on and off.
d. it works well in conjunction with the pressurized reservoir system.

32. (210) Which of the following situations is most likely to occur in the hydraulic pressure regulator when it is kicked in and the power pump is running?

a. Pressure below the piston is decreasing.
b. Pressure on top of the piston is decreasing.
c. The check valve is open, the bypass is closed, and the power pump is unloaded.
d. The check valve is open, the bypass is closed, and the power pump is under load.

33. (210) To increase the kick-out pressure of a selective-type double area pressure regulator, the mechanic should

a. screw down the piston and off-seat the poppet.
b. adjust the screw clockwise, lengthening the rod.
c. turn the adjusting screw counterclockwise, allowing the rod to rise.
d. increase the tension on the large spring by turning the adjusting lever.

34. (210) The pilot reports that all the hydraulic units on the aircraft seem to operate slower than normal at all altitudes and during landing. He also states that the hydraulic pressure gage indicates that pressure remains below normal. These symptoms indicate that the

a. kick-out pressure needs adjusting.
b. micronic filter element needs replacing.
c. pressure regulator bypass valve is leaking.
d. pressure regulator check valve is defective.

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35. (210) A leaking check valve in a pressure regulator will

a. cause the kick-in pressure to be lower.
b. not cause the kick-out or kick-in pressure to change.
c. cause the kick-out pressure to be higher than normal.
d. cause the relief valve to relieve the fluid back to the reservoir.

36. (211) In a hydraulic system using an accumulator, the preload pressure should be serviced to a

a. minimum of 300 psi.
b. maximum of 1000 psi.
c. pressure equal to what system pressure will be.
d. pressure greater than required to operate any one unit.

37. (211) In a hydraulic system using a piston type accumulator, a passage is drilled from the fluid side of the piston to the space between the two piston seals to

a. allow for lubrication of the seals.
b. eliminate the need for backup rings.
c. prevent the top seal from being damaged.
d. allow easy installation of the piston seals.

38. (211) In a hydraulic system using the self-displacing-type accumulator, hydraulic fluid is added to the system

a. during accumulator overhaul cycle.
b. while the accumulator preload is discharged.
c. from the A–2 portable hydraulic test stand.
d. by using the hand pump connected to the main reservoir.

39. (211) When performing a leakage test on a bladder type accumulator,

a. apply 5000 psi hydraulic pressure.
b. the specified preload will be put in.
c. it must hold the pressure for a minimum of 24 hours.
d. the check will be performed with the unit installed on the aircraft.

40. (212) If a relief valve with a ball seat area of 1/6 square inch is to relieve at 1800 psi, the spring force behind the ball should be

a. 300 pounds with no back pressure.
b. greater than the cracking pressure.
c. about 1500 pounds with back pressure.
d. about 2100 pounds with back pressure.

41. (212) The back pressure effect on the ball of a balanced type relief valve is eliminated by

a. reducing the spring force.
b. reducing the size of the ball.
c. turning the adjustment screw clockwise.
d. attaching a rod to the back side of the ball.

42. (212) With a relief valve installed in the aircraft main hydraulic system, how do we adjust its relieving pressure?

    a. The relief valves are preset and should never require adjustment.
    b. Run the engine and make the adjustments while watching the test gage.
    c. Pressurize the system with the hand pump and set the cracking pressure.
    d. Use a test stand for pressure and watch the cockpit indicator for the relieving pressure.

43. (212) The aircraft hydraulic system is set for 300 psi while one of the actuators is designed to work with only 1000 psi pressure. What is to be done to operate this actuator safely?

    a. The pressure regulator and relief valves should be reset.
    b. Reduce the tubing size and this will decrease the pressure.
    c. Reduce the accumulator preload pressure and unload the pump sooner.
    d. Install a pressure reducer valve of the proper size in the actuator line.

Chapter 4

44. (213) When a closed-center selector valve is in the neutral position, the pressure manifold will

    a. be connected to the return line.
    b. always be connected to the actuated unit.
    c. always be pressurized whenever there is system pressure available.
    d. be returning the fluid to the reservoir from the retract side of the actuator.

45. (213) Three-way selector valves in hydraulic systems serve to

    a. direct fluid pressure into one of three different lines.
    b. build up high pressures through temperature increases.
    c. operate a mechanism electrically in one direction only.
    d. operate a mechanism hydraulically in one direction only.

46. (213) Four-way selector valves have

    a. four sets of poppets.
    b. all poppets on seat when in neutral.
    c. a relief valve venting to the return line.
    d. a device to direct fluid flow in four directions.

47. (213) What would be the effect on system operation if the piston screws in a poppet type *radial* selector valve were adjusted and shortened too much?

    a. The system actuators will operate slower than normal.
    b. The actuators will operate faster than normal.
    c. The system fluid will become excessively hot.
    d. There would be no noticeable effect on system operation.

48. (213) The variable-restrictor control valve is generally used to control

a. the bay door opening system.
b. extension and retraction of the gear only.
c. the operation of the flight control surfaces.
d. operation of test stands, since it is an open-center system.

49. (214) An orifice check valve is usually installed in a hydraulic system to

a. restrict the flow of fluid leaving the hydraulic actuating cylinder.
b. limit the travel of a hydraulic actuating cylinder in both directions.
c. allow full flow in one direction and restricted flow in the opposite direction.
d. allow restricted flow in one direction and no flow in the opposite direction.

50. (214) The snubber used to prevent erratic readings on pressure gages due to system surges is usually

a. made by drilling tiny holes in a piece of steel.
b. a combination internal bypass and safety shutoff valve.
c. an orifice check valve installed in the line leading to the gage.
d. made by drilling a hole in a piece of steel and inserting a pin into it.

51. (214) Which of the following valves is normally installed at the inlet port to allow two independent systems to opeate the same actuator?

a. Shuttle valve.
b. Balanced relief valve.
c. Combining check valve.
d. Slide type selector valve.

52. (215) If fluid does *not* split evenly in the flow equalizer, a

a. free-floating piston shifts position.
b. variable orifice changes opening size.
c. check valve opens on the side with the lesser pressure.
d. check valve opens on the side with the greater pressure.

53. (215) Hydraulic fuses are used in jet aircraft hydraulic systems to

a. maintain a constant rate of flow to a subsystem.
b. prevent any fluid loss in the event of a broken line.
c. prevent excessive fluid loss in the event of a broken line.
d. prevent excessive rate of flow to a subsystem in which it is installed.

54. (215) A hydraulic fuse in a pressure line fused. A check of the system showed no leaks. What could be a probable cause?

a. A leaking poppet valve in the selector valve.
b. An incorrect setting of the pressure regulator.
c. Too small an opening in the finger strainer in the line.
d. The fuse is undersized for the amount of fluid required.

55. (216) Why do we use hydraulic actuators?

a. They are cheap and trouble free.
b. They transform fluid pressure into mechanical force.
c. They are the only means of controlling operation.
d. They change rotary motion into linear motion.

56. (216) A double-acting unbalanced actuator is used on the aircraft because it provides

a. equal pressure in two different directions.
b. the higher pressure needed to overcome the extra spring force.
c. us with a means of having a mechanical lock on the unit.
d. more force in one direction than in the other.

57. (216) The actuator that is designed to reduce damage due to excessive force or speed is

a. the internal-snubber type.
b. the double-acting balanced type.
c. charged with the hard strut servicing kit.
d. used only on combat aircraft operating on rough fields.

58. (216) The only manner in which the internal-lock-type actuator can be extended is by

a. applying pressure to the extend port and hydraulically unlocking it.
b. applying pressure to the unlock cylinder and then allowing it to extend by spring action.
c. bleeding the pressure from the hydraulic lock side and letting the weight extend the actuator.
d. first mechanically unlocking the unit and then applying the pressure to extend it.

Chapter 5

59. (217) The primary purpose of the torque arms used on aircraft landing gear struts is to

a. keep the gear aligned for retraction.
b. limit the maximum extension of the strut.
c. keep the wheels in the correct alignment.
d. allow the wheels to turn when steering the aircraft.

60. (217) The hydraulic fluid level of an air-oil shock strut is checked by

a. removing the high-pressure air valve.
b. checking the cockpit quantity indicator.
c. no checks required as it is a closed system.
d. observing the position of the fluid indicator pin.

61. (217) A disadvantage of servicing shock struts on an aircraft using the hard-strut method is that

a. not enough fluid is used.
b. the strut could bottom under a load and damage the gear.
c. too much fluid is used which acts like a solid and causes damage.
d. the struts bottom all the time and eventually will damage the gear.

62. (217) If the aircraft uses a nose gear shock strut depressurization system, what must be done each time the aircraft lands?

a. The nose gear shock strut must be serviced with air.
b. The strut must be removed and replaced with a serviceable unit.
c. Nothing immediately, but following the last flight of the day, the strut will be serviced.
d. The pilot will automatically extend the shock strut to the proper ground level extension.

63. (218) During maintenance of shock struts, the strut will be replaced when

a. it will not hold a preload air charge.
b. the aircraft has performed 100 landings.
c. the O-ring seals and gaskets are worn.
d. any scratches have penetrated the chrome plating.

64. (218) What method is commonly used to inspect ferrous parts of shock struts for cracks?

a. X-ray.
b. Microscopic.
c. Fluorescent.
d. Magnetic particle.

65. (218) Corrosion treatment of shock struts will include painting with

a. aluminum lacquer and waxing the entire surface.
b. camouflage color and clear lacquer.
c. zinc chromate primer and rechroming.
d. two coats of zinc chromate primer and two coats of aluminum lacquer.

66. (218) What is the basic theory of operation of the liquid-spring shock strut?

a. Liquids can be compressed at high pressures.
b. Liquids are uncompressible at high pressures.
c. Fluid pressure increases as the velocity increases.
d. Fluid pressure decreases as the velocity decreases.

67. (218) Servicing of an aircraft using a liquid-spring shock strut requires that

a. the strut be removed from the aircraft and returned to field maintenance.
b. a compressor of extremely high pressure be used to preload the cylinder.
c. all jacks be removed and the wings rocked periodically during servicing.
d. all weight be removed from the aircraft and the strut fully extended.

68. (219) The aircraft uses the vane-type shimmy damper. The nose wheel does not shimmy but is difficult to move normally and does not want to trail. What could be a probable cause?

a. The hydraulic fluid supply is low.
b. An orifice with too large an opening is used.
c. The size of the orifice has been adjusted down too small.
d. The torque arms have been overtightened and are not free to move.

69. (220) The followup mechanism on nose wheel steering units

a. makes it easier to turn the wheels.
b. returns the wheel to centered position.
c. allows unrestricted flow of return fluid.
d. matches the amount of wheel turning to the amount of pilot's control wheel turning.

70. (220) In addition to nose wheel shimmy control, what other feature do we find on most aircraft with nose gear?

a. Nose wheel steering.
b. Nose wheel braking.
c. Mechanical retraction.
d. Dual tires installed for safety.

Chapter 6

71. (221) A slave brake system is used on large aircraft mainly because

a. more braking pressure is furnished.
b. weight is reduced by using smaller tubing.
c. it provides a more rapid brake application.
d. it eliminates hydraulic lines from the cockpit.

72. (221) Generally, the loss of main hydraulic system pressure on most fighter aircraft will

a. *not* affect the normal braking action.
b. require the use of the emergency brake.
c. result in loss of normal brake pressure.
d. result in partial loss of braking pressure.

73. (221) When an independent brake system on an aircraft is in the parked condition, the

a. master cylinder will be in the OFF position.
b. parking T-handle must be pulled to release the brakes.
c. master cylinder must be locked in the applied position.
d. braking pressure is maintained by the fluid applied from the main system.

74. (221) When a Gladden master cylinder is in the parked condition, the

a. thermal expansion will increase the brake pressure.
b. thermal expansion will decrease the brake pressure.
c. parking brake handle must be left in the parked position to hold.
d. thermal expansion in the brake line is relieved by the compensating chamber.

75. (221) In a *pneumatic* brake system using a master cylinder, the fluid leaving the master cylinder goes to an air

a. debooster.
b. slave valve.
c. relay valve.
d. shuttle valve.

76. (222) The unit that uses main system pressure to help the pilot in applying the brakes is the

a. brake adjust valve.
b. brake master boost cylinder.
c. electrically operated power brake control valve.
d. hydraulically operated power brake control valve.

77. (222) A leaking poppet in a single Bendix power brake control valve will most likely cause the main system pressure to leak away

a. only when the brakes are applied.
b. only when the brakes are not applied.
c. whether the brakes are applied or not.
d. when there is no check valve installed before the PBCV.

78. (222) Which of the following would be the most logical cause if a Bendix power brake control valve fails to provide pressure to the brake assembly?

a. A broken leaf spring.
b. A clogged return port.
c. A badly leaking piston seal.
d. The pressure poppet stuck open.

79. (222) When adjusting the brake pressure on an aircraft using a Bendix power brake control valve, the effective length of the spring is extended in order to

a. increase pressure.
b. decrease pressure.
c. decrease piston travel.
d. increase piston travel.

80. (222) To bleed the power brake control valve system by the internal pressure bleeding method, the pneudraulic mechanic shoulld first

a. drain the entire system of fluid.
b. fill the main hydraulic reservoir to capacity.
c. be certain that the system pressure is released.
d. open the wheel bleeder several turns.

81. (223) What volume of fluid will be displaced in a hydraulic cylinder if the force on the face of the piston is 600 pounds, the piston travels 4 inches, and the pressure on the piston face is 200 psi?

a. 3.0 cubic inches.
b. 5.0 cubic inches.
c. 1.33 cubic inches.
d. 12.0 cubic inches.

82. (224) Application of one of the basic laws of physics reveals that during the landing of an aircraft, the

a. kinetic energy possessed by the aircraft increases as it slows down.
b. brakes are applied to decrease the kinetic energy of the aircraft.
c. kinetic energy developed will depend on the area of the braking surface.
d. kinetic energy developed by forward motion is opposed by the gravitational force of the earth.

83. (224) Which of the following applies when the rolling speed of a landing aircraft is reduced by the application of multiple disc brakes?

a. The piston return spring makes contact with an outer bronze disc.
b. The bronze discs are slowed down by friction with the steel discs.
c. Fluid forces the annular piston against the face of the outer nonrotating disc.
d. A steel disc makes contact with the insulator ring and dissipates heat from the remaining discs.

84. (225) The clearance of expander tube brakes having no manual means for adjustment is *primarily* determined by the

a. thickness of the block.
b. age of the expander tube.
c. restraining force of the retraction spring.
d. amount of fluid retained in the expander tube.

85. (225) The maximum outward expansion of the expander tube on the expander tube brake is primarily limited by the

a. applied pressure.
b. torque lugs on the brake frames.
c. thickness of the expander tube shield.
d. distance between the blocks and brake drums.

86. (225) The first step in adjusting the expander tube brake adjuster valve is to

a. apply the brakes and turn the adjuster screw clockwise.
b. release the brakes and turn the adjuster screw clockwise.
c. apply the brakes and turn the adjuster screw counterclockwise.
d. release the brakes and turn the adjuster screw counterclockwise.

87. (226) What type of brake makes use of *semiannular* pistons?

a. Spot disc.
b. Multiple disc.
c. Expander tube.
d. Segmented rotor.

88. (226) If the automatic adjuster clamp of the segmented rotor brake is loose, the brake

a. cannot be applied.
b. will tend to drag.
c. eventually will not apply.
d. eventually will lock when applied.

89. (227) In a hydraulic system using a spot disc-type brake, one of the highly desirable features of this type brake is the

a. mechanical adjustment.
b. rapid heat dissipation.
c. use of it mechanically.
d. use of a master cylinder with it.

90. (227) The dual spot disc brake components whose condition is most important for proper self-adjusting are the

a. torque nut and spring guide.
b. piston and cylinder surfaces.
c. adjusting pin and adjusting pin grip.
d. adjusting pin and internal retaining ring.

91. (227) If the adjusting pin torque nut on a single spot disc brake is too tight, which of the following will result?

a. The brakes will drag.
b. Braking action will be lost.
c. The lining clearance will decrease.
d. The adjusting pin will be forced inward.

92. (227) The running clearance of dual spot disc brakes is

a. the same for both the single and dual disc brakes.
b. usually greater than that of a single disc brake of the same diameter.
c. determined by the friction of the self-adjusting pin and pin grip.
d. determined by the thickness of the compensating shim.

93. (228) Some of the leading factors that cause a high degree of wheel and brake failures are

a. poor maintenance, good inspections, and unconscientious mechanics.
b. poor maintenance, careless inspections, and conscientious mechanics.
c. poor maintenance, careless inspections, and unconscientious mechanics.
d. careless inspections, good maintenance, and unconscientious mechanics.

94. (228) Brake assemblies should be returned to depot for overhaul

a. after the third lining change.
b. before the third lining change.
c. whenever a piston seal is changed.
d. before the second piston seal change.

95. (228) In high performance aircraft braking systems, the skid control system first comes into play when the

a. wheel locks and slides.
b. brakes are not applied.
c. wheel starts to slide but still is rotating.
d. aircraft weight is on its wheel after landing.

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AIRCRAFT PNEUDRAULIC REPAIRMAN
(AFSC 42152)

Volume 3

Pneudraulic Systems and Principles of Operation

Pneudraulic Systems and
Principles of Operation

Extension Course Institute
Air University

Preface

THE PREVIOUS two volumes of Course 42152, *Aircraft Pneudraulic Repairman*, have given you information on pneudraulic functions in addition to the operation and maintenance of pneudraulic components. Now, in Volume 3, we will use this information in explaining pneudraulic systems and their principles of operation. Chapter 1 covers aircraft familiarization. In Chapter 2, we will discuss electrical fundamentals and trouble analysis. We continue with Chapter 3 on pneudraulic power systems, discussing both the hydraulic and pneumatic systems; then on to Chapter 4, which covers hydraulic actuating units. Finally, in Chapter 5, we discuss aircraft emergency pneudraulic systems, such as emergency flight control, landing gear warning, and emergency wheel brake.

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Material in this volume is technically accurate, adequate, and current as of January 1972.

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Aircraft Familiarization

NOT SO VERY LONG ago, physics and aeronautics were generally considered obscure and difficult subjects. These subjects were of little use to anyone but scientists and aircraft design engineers. Today, the situation is quite different; as pneudraulic repairmen, we must have an understanding of physics and aeronautics to maintain our flight control hydraulic systems. Most aircraft use hydraulically actuated flight controls.

2. Our study in this chapter of physical laws and aeronautical principles will aid you in understanding the systems you will maintain. In order to understand the principles of hydraulic and pneudraulic power systems, you will learn some basic facts about energy and matter. You will get to know something about the atmosphere and how our aircraft fly in it. You will learn the function of the surfaces which control flight and which are powered hydraulically. Finally, the chapter will cover construction and component arrangement features and a system of aircraft identification.

1. Basic Laws of Energy and Matter

1-1. Energy falls into two categories: potential energy and kinetic energy. The laws of transformation and conservation of energy will be studied, along with the relationship between energy and matter. Matter will be explained in its three stages: solids, liquids, and gases.

1-2. **Energy.** Energy is the ability to do work. Work is performed when a force acts on a body and moves it. The motion is the clue to the concept of work, and without it there is no work. Imagine some Egyptian slaves, thousands of years ago, struggling to move a block of stone for one of the pyramids. The slaves push and sweat, but the stone does not budge an inch; so, no work has been done. They rest a little, and return to the job and push harder than before. This time the stone moves. They have done some work. The amount of work is equal to the force they exert times the distance the block was moved.

1-3. In our technical age, we need a unit of measurement for work. The unit of work commonly chosen is called a foot-pound. A foot-pound of work is the work required to move 1 pound a distance of 1 foot. The Egyptian slaves learned that work was an expenditure of energy that accomplished something. So, let's examine a few facts about energy.

1-4. *Potential energy.* Potential energy is energy at rest. A tightly stretched spring is ready to do work; so, it possesses energy. Compressed air has only to be released in order to do work; it, too, has energy. A lifted clock weight is able to make the clock run because it has stored energy in its raised position. These are all examples of potential energy. A body has potential energy because of its position.

1-5. *Kinetic energy.* Kinetic energy is energy in motion. A baseball flying through the air possesses kinetic energy. When you catch the ball, its kinetic energy warms your glove and stings your hand. A moving automobile, a moving stream of water, and the wind are also examples of kinetic energy. Any body in motion is able to do an amount of work equal to its kinetic energy. Conversely, if an amount of work is done to accelerate a body, the body requires an equal amount of kinetic energy.

1-6. *Transformation of energy.* Energy can be changed from one form into another in many different ways. Radiant energy of the sun strikes the earth; it is changed into heat energy and warms the earth. When sunlight falls on the leaves of plants, it is transformed into chemical energy. Electrical energy becomes sound energy in the telephone receiver, in the loudspeaker, and in bells. When gunpowder is fired, the chemical energy that was stored in it is released. It is partly as heat and partly as mechanical energy in propelling a bullet.

1-7. *Conservation of energy.* The law of the conservation of energy states: energy can be neither created nor destroyed. No one has ever found a way to create energy out of nothing. No machine has been found that delivers more energy than is put into it. We can only use what is already here. A machine is not only helpless to create energy, but unable to destroy energy. A machine does not deliver all of the energy that is put into it. The energy that is not delivered is not destroyed. It is usually changed into heat energy. Fuel may be wasted by going up the flue in smoke; nevertheless, energy goes up with the smoke.

1-8. **Matter.** Matter is anything which occupies space and has weight. Since it can be weighed, it has mass. It also has size, since every piece of matter has length, width, and height. As stated earlier, the three states of matter are solids, liquids, and gases. Matter may appear in any one of these forms. It may also undergo a physical change to another state as the result of a rise or fall in temperature. For example, water may be readily changed to ice (the solid state) or steam (the gaseous state). This is done simply by increasing or decreasing its temperature. Its chemical makeup remains unchanged.

1-9. *Solid.* A solid has definite shape and a definite volume. Its molecules offer a great resistance to change and have a strong attraction for each other.

1-10. *Liquid.* A liquid has a definite volume but no definite shape. Its molecules have much less attraction for each other. A liquid takes the shape of its container.

1-11. *Gas.* A gas has no definite volume and no definite shape. Its molecules have almost no attraction for one another and are relatively far apart. A gas always fills its container.

1-12. You now have a basic understanding of work, energy, and forms of matter. In the next section, these truths will find practical application in the science of aerodynamics. A thought to keep in mind—no mechanical device can do its job unless the basic laws of physics (or nature) are obeyed in its design.

2. Aerodynamics

2-1. Aerodynamics deals with the motion of air and the forces that act on solids moving through the air (air is fluid and in a gaseous state). Sometimes the definition is expanded to include other gaseous fluids. It should be pointed out that aerodynamics is not limited to aircraft flight. The swaying of a bridge in the wind is an example of aerodynamic action. However, the chief problems of aerodynamics have to be met in aeronautics; therefore, it is in the field of aviation that aerodynamics has its greatest value. Let us begin, then, with a study of the atmosphere.

2-2. **The Atmosphere.** Air is a mixture of several gases. However, for all practical purposes, we may consider it as one-fifth oxygen and four-fifths nitrogen. It surrounds the earth and extends upward for hundreds of miles. Perfectly dry air weighs 0.07651 pound per cubic foot under standard conditions at sea level. The atmosphere everywhere exerts a uniform pressure in all horizontal directions. The pressure of the atmosphere plays a major role in the design and flight of an aircraft. One of the principal problems is the pressure differences at different altitudes. As we increase altitude, the pressure decreases. At sea level on a standard day, the pressure is 29.92 inches of mercury as indicated on a manometer. At 50,000 feet, the pressure drops to approximately 3.44 inches of mercury. (The pressure of 1 inch of mercury (Hg) is equal to the weight of 1 inch of mercury.) This pressure variation has a decided effect on the flight characteristics of an aircraft. There are many other factors of atmosphere which affect flight characteristics. Three of these factors are temperature, density, and humidity. We will discuss these next.

2-3. *Temperature.* We are all familiar with the sensations of heat and cold. While these are unreliable indicators, they agree with other observations on the effects of heat. An object that feels hot will show its hot condition in other ways. To take two examples: a metal rod is a little longer when hot than when cold; a fixed volume of gas exerts a greater pressure when it is heated.

2-4. Terms such as "hot," "cold," "warm," and "cool" are used in ordinary speech. But, they do not adequately express the temperature of a substance. Temperature is the degree of heat measured on a definite scale which, in this case, is the thermometer.

2-5. *Density.* Density may be defined as mass (weight) per unit volume. With a constant temperature, density varies directly as the pressure varies. Air can be either compressed or permitted to expand. When compressed, the same quantity (mass) of air occupies a smaller space. When the pressure decreases, the same quantity of air expands and occupies a larger space. Similarly, with a constant pressure the density of the air varies directly with temperature. In the atmosphere, density falls off rapidly with height above sea level. Both temperatures and pressure decrease with increasing altitude.

2-6. Air has a low density at a high altitude, and then it is often referred to as being *thin*. In a like manner, air at a low altitude has high density, and it is often referred to as being *thick*. The difference, or change, in density greatly affects the flight of an aircraft. Although an aircraft can fly faster at a higher altitude for a given thrust, its maneuverability is decreased. The increase in speed is a result of the decrease in drag. There is much less resistance to aircraft flight at higher altitudes. This is because there are fewer molecules of air for a given volume as we increase the altitude. This results in the control surfaces being less effective at extremely high altitudes. Maneuverability becomes a very serious problem.

2-7. Temperature and pressure variations at any constant altitude also play an important part on density variation. On hot days or in tropical climates the air becomes less dense. Then an aircraft responds to control movements less readily than on a cold day or in the arctic regions. Another factor affecting flight of aircraft is humidity.

2-8. *Humidity.* Humidity is moisture, or dampness, in the atmosphere. The maximum amount of water vapor that the air can hold depends on the temperature; the higher the temperature of the air, the more water vapor it can contain. By itself, water vapor weighs about five-eighths as much as an equal volume of perfectly dry air. Therefore, when air contains 10 parts of water vapor and 90 parts of dry air, it is less dense than dry air.

2-9. Assuming that the temperature and pressure remain constant, the density varies with the humidity. On humid days, the density is less than on dry days; therefore, an aircraft requires a longer takeoff distance. Even engine power is affected by the humidity. The higher the humidity, the less power an engine puts out for the same control settings. The aircraft also reacts more slowly to control surface movement.

2-10. We have talked about the characteristics of the atmosphere in which the aircraft flies. Now let us look at some of the principles governing flight.

2-11. **Principles of Flight.** To understand his job, the pneudraulic specialist must have some knowledge of the principles of flight. No doubt, man got the idea of flight from watching the birds soar gracefully overhead. His early attempts at flight were, for the most part, fantastic, if not fatal. He even tried to imitate the birds by attaching wings to his arms and shoulders. It just did not work, because in his early attempts to fly, man didn't know enough about aerodynamics. First, let us review the characteristics of an airfoil and the forces acting upon it in flight.

2-12. *Airfoils.* Figure 1 shows a typical airfoil. You will note that the two edges of the airfoil differ in appearance. The edge that faces into the wind in flight is called the leading edge. The other edge is called the trailing edge. A reference line often used in discussing an airfoil is the *chord* line. This is a straight line drawn through the airfoil. The line connects the farthermost points of the leading and trailing edge. It is about parallel to the longitudinal axis of the aircraft. A most important factor of an airfoil's lifting ability is *camber*. Camber is the curve of the surface of an airfoil from the leading edge to the trailing edge. Notice, in figure 1, the upper camber is longer than the lower camber. This difference has an effect on the amount of lift (and drag) the airfoil produces.

2-13. Now let's review the four aerodynamic forces acting upon an aircraft: lift, weight, thrust, and drag. The lift of the airfoil acts upward at a right angle to the direction of the relative wind. Relative wind is the airstream striking the moving airfoil. The weight (gravity) acts vertically downward from the center of gravity of the aircraft. Thrust is the force which moves the aircraft forward during flight. Drag is the resistance of the atmosphere to the aircraft's forward motion. When the aircraft is in straight and level unaccelerated flight, the lift equals the gravity and the thrust equals the drag. Figure 2 shows how the opposing forces balance each other. The lift forces the airfoil up; at the same time, the resistance (drag) pulls the wing backward. The resultant action, consequently, is a combination of both motions, upward and backward.

2-14. The other two forces, thrust and weight, affect the airfoil movement. The thrust causes the airfoil to move forward. The weight (gravitational pull) causes the airfoil to fall toward the earth. As you will note, the forces act in different directions and balance each other. If the lift is as great as the weight, the aircraft neither rises nor falls (climbs nor dives); if the thrust is as great as the drag, the aircraft does not move either faster or slower but moves at a constant speed. To go faster, we merely make the thrust larger than the drag, and the aircraft accelerates. Soon the thrust and drag

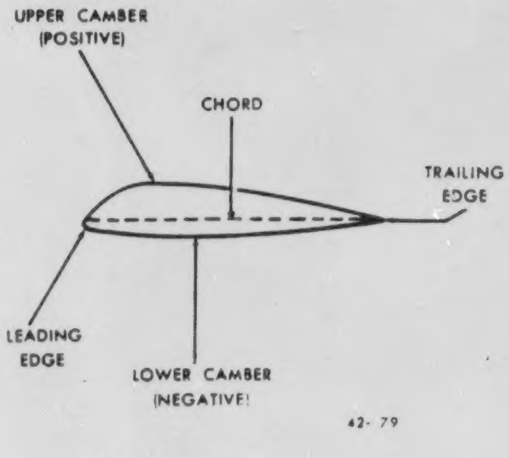

Figure 1. Typical airfoil section.

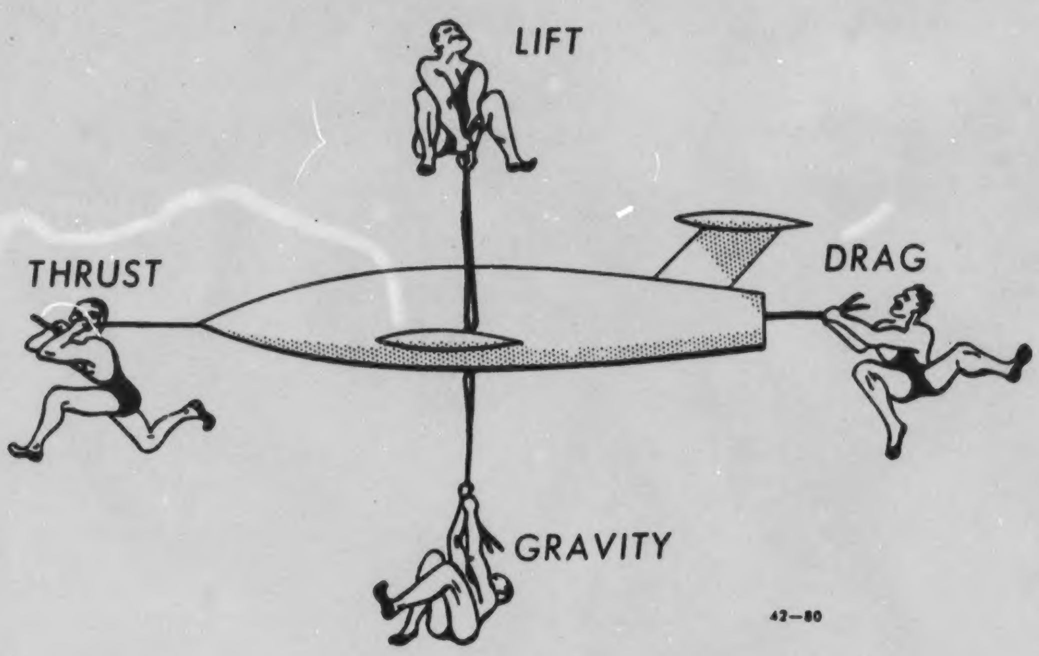

Figure 2. Four forces in flight.

again equalize. Now the aircraft no longer accelerates but moves ahead at a constant speed, but faster.

2-15. The last two principles to consider in our review of flight are: the laws of lift and of the venturi. The first law can best be illustrated by holding your hand out of the window of a moving automobile. As you tilt your hand, the force of the air against your hand has a tendency to move it. The airfoil, in this case, is your hand, and it deflects the wind. This action creates a pressure on the lower surface of your hand, forcing it upward and backward (lift and drag). The second law relates to the venturi principles. You learned about venturis in Section 2 of Volume 2. There we applied the principles of jet pumps, but they also apply to airfoils. When an airfoil moves through the air, both the airfoil shape and angle of attack cause the air to be deflected. The deflection slows the air below the airfoil, causing a high-pressure area under the surface. The air moving across the upper surface of the airfoil travels a longer distance. This causes an increase in air velocity. This increase in velocity produces low pressure next to the upper surface of the airfoil. In this manner, a pressure differential acting on the top and bottom of the wing creates the lift. As the speed of the airflow increases, the pressure differential (and lift) also increases.

2-16. We have already pointed out that drag is the resistance of atmosphere to the airfoil's forward motion. The drag will always act parallel to the relative wind. The relative wind is the direction of the airflow with respect to the airfoil. If an airfoil is moving forward horizontally, the relative wind moves rearward horizontally. If the airfoil is moving forward and downward, the relative wind moves rearward and upward. The angle of attack of an airfoil directly controls the distribution of pressure above and below it. The angle of attack can be defined as: the angle between the chord of an airfoil and the direction of the relative wind. Whenever one of the conditions is changed, it will affect another. For example, if speed is increased, angle of attack will change. This speed increase causes a pressure change above and below the airfoil. The pressure change causes the aircraft to climb because of a greater lift from the airfoil. To maintain *constant* lift, the airfoil's velocity must be decreased as its angle of attack is increased. You can see from this, then, how the necessary lift for flight is produced.

2-17. *Flight characteristics.* There are three axes about which an aircraft may turn, as shown in figure 3. These axes are imaginary lines passing through the aircraft's center of gravity. You might think of these axes as imaginary axes around which the aircraft turns like a wheel. Each of the axes is perpendicular to the other two. The axis that extends from the nose of the fuselage to the tail is the longitudinal axis. The axis that extends crosswise, from wingtip to wingtip, is the lateral axis. The axis that passes vertically through the center of gravity is called the vertical axis. The motion about the longitudinal axis is called roll. The motion about the lateral axis is called pitch. Motion about the vertical axis is called yaw. When the attitude of an aircraft is changed in flight, it will move around one or more of its axes.

2-18. Now you have become familiar with a few of the characteristics of flight and the different forces that act on the aircraft. Let us next look at the various surfaces used in controlling movements of the aircraft in flight.

2-19. **Flight Control Surfaces.** It is very simple to change the direction of a bus, car, or truck by merely turning the steering wheel. This movement, however, is only on one plane—the lateral. By contrast, the directional movement of an aircraft is around three axes—lateral, longitudinal, and vertical. It represents an unlimited number of planes of movement. This movement of the aircraft is controlled primarily by flight control surfaces. These are located on the trailing edges of the wings and stabilizers. Figure 4 shows various flight control surfaces.

2-20. *Elevators.* The elevators are used to make the aircraft dive or climb. This is done by controlling the angle of the surface with respect to the air flowing over it. The elevators are hinged to the trailing edge of the horizontal stabilizer. They are connected so that they always operate together. Forward and aft operation of the control stick moves the elevators up and down. This movement controls the aircraft about the lateral axis. Downward force on the tail causes the nose to rise and increases the wing angle of the attack. This increases the lift and causes the aircraft to climb if the speed is maintained. If the pilot moves the control forward, the elevators move downward. The lift will decrease and the aircraft will lose altitude.

2-21. *Rudder.* The rudder is hinged in a vertical position at the trailing edge of the vertical stabilizer. It is controlled by the movement of the rudder pedals. It guides the movement of the aircraft about the vertical axis. When the pilot applies pressure on the right pedal, the rudder moves to the right. The tail of the aircraft is thus forced to the left, rotating the aircraft about its vertical axis. When the tail is moved to the left, the nose of the aircraft is

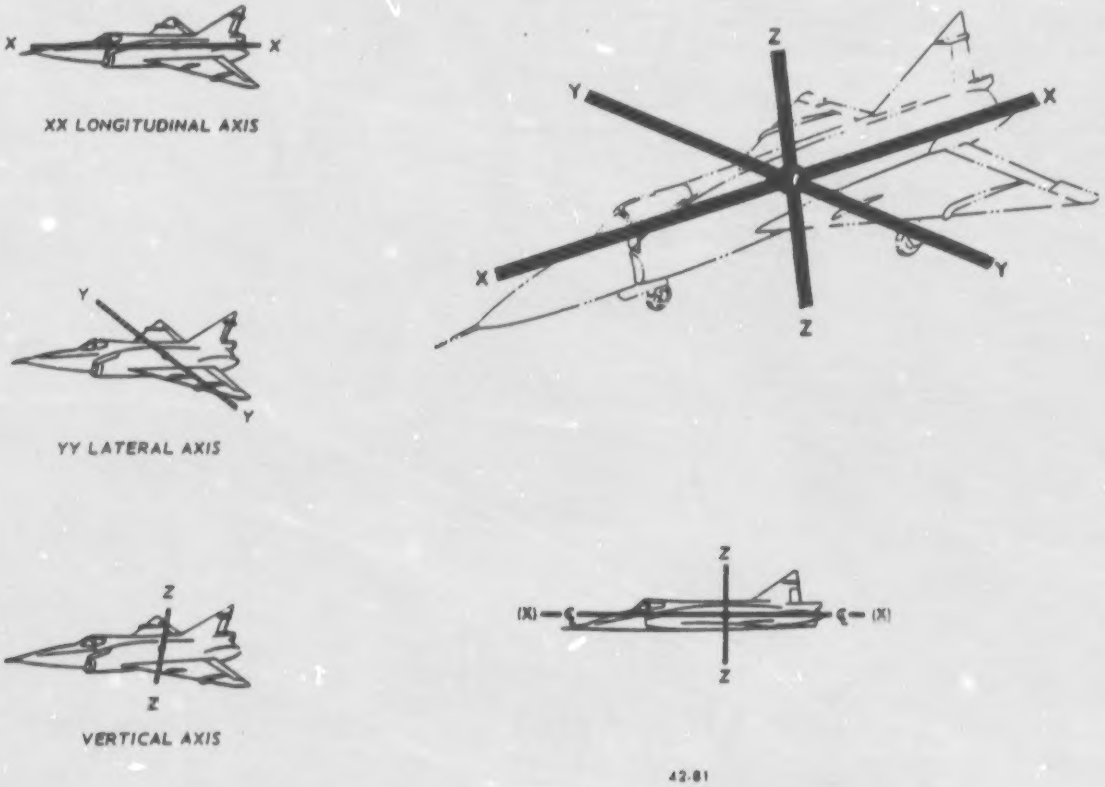

Figure 3. Three flight axes of an aircraft.

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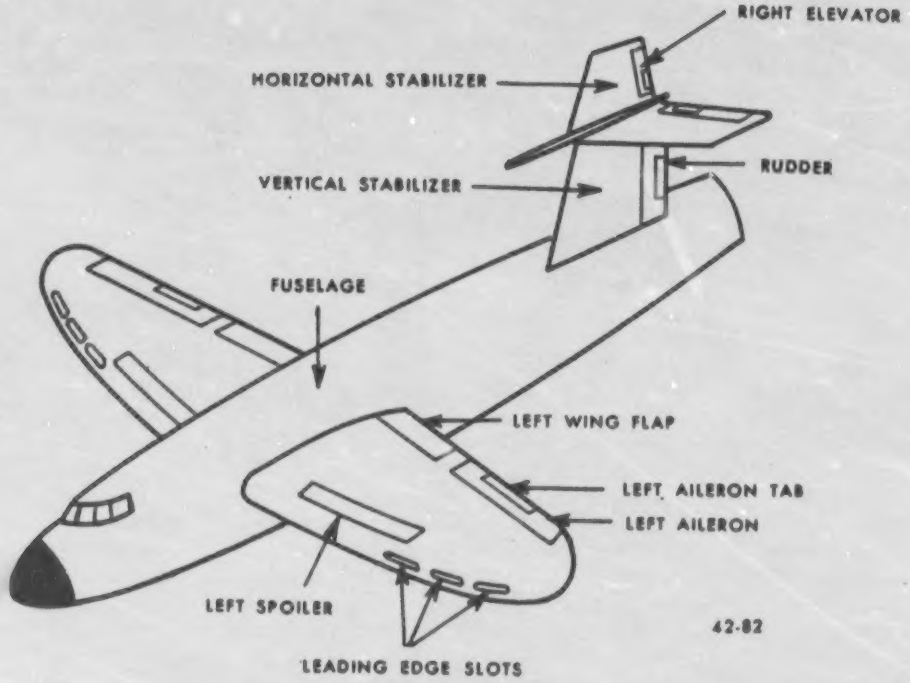


Figure 4. Type of flight controls.

moved to the right. Pressure applied to the left pedal reverses this action.

2-22. If the pilot makes a turn with a rudder alone, he normally finds that the aircraft will sideslip. This is similar to an automobile trying to take an unbanked curve too fast. The skidding is caused by centrifugal force. The pilot prevents this skidding (or sideslipping) by banking. Banking is the coordination of rudder and ailerons in a turn.

2-23. *Ailerons.* The ailerons are located in the trailing edge and toward the tips of the wings. Their movement is controlled by the pilot's control stick or wheel. From the pilot's control the linkage is arranged so that if one aileron goes up the other goes down. For a right turn, the right aileron is raised, which will force that wing down. The left aileron has moved down, which results in more lift on the left wing; the wing will then rise.

2-24. *Movable horizontal stabilizer.* During flight at transonic (at speed of sound) speeds, the airflow over the horizontal stabilizer creates shock waves. These shock waves form air fences ahead of the elevators that result in the loss of elevator control.

2-25. To correct this, present-day aircraft are equipped with a movable horizontal stabilizer. It gives the pilot faster and firmer control over his aircraft. The control stick is connected to the horizontal stabilizer through mechanical and hydraulic units. These aircraft have no elevators, and the pilot flies the aircraft with the horizontal stabilizer. When the stabilizer is rotated, its leading edge moves down and the aircraft tail is forced down; the nose of the aircraft moves up.

2-26. *Elevons.* The flight of delta-wing aircraft control surface requires a different arrangement. The trailing edge of the wing will provide the only place for mounting. Both aileron and elevator are combined in one surface called elevons. These are illustrated in figure 5. They are connected in such a way as to operate together as elevators when the control stick is moved forward and aft. They operate as ailerons when the stick is moved from side to side.

2-27. *Tabs.* Tabs are of three types: fixed, trim, and booster. They are located on the trailing edge of controls such as the elevator, rudder, and ailerons. Their reaction in the airstream, however, is the same in all three cases. For example, we wish to trim an aircraft in pitch. In order to raise the nose of the aircraft, the tab must be moved down. The reason for this is clearly shown in figure 6. The primary control surface, in this case the elevator, is hinged to the horizontal stabilizer. The tab in turn is hinged to the elevator. A movement of

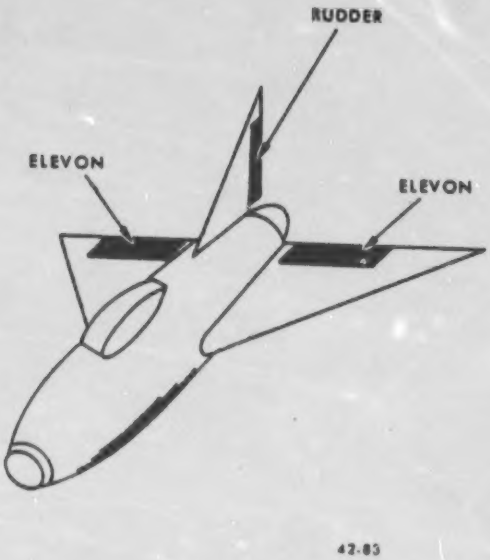


Figure 5. Delta wing configuration.

the tab causes a powerful movement to be exerted on the primary control surface. The result of this force is a small movement of the elevator in the opposite direction. Therefore, if the tab is moved down, the elevator will move up. Since the aircraft responds only to the action of the primary control, the tail will drop. This raises the nose of the aircraft.

2-28. The fixed tab is attached permanently to the trailing edge of the primary surface. It is bent uniformly and is manually adjusted while the aircraft is on the ground. Its purpose is to compensate for an unbalanced condition of the control surface.

2-29. The trim tab is more complex in construction than the fixed tab. It is controllable manually by the pilot or automatically by an electric motor. Therefore, trim can be changed as conditions, such as wind direction or load, change.

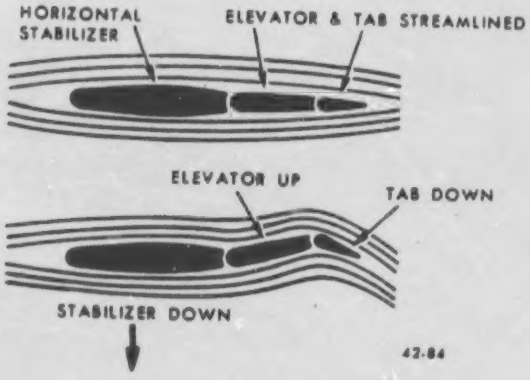


Figure 6. Principle of tab operation.

2-30. The booster tab is sometimes called a servotab. It is used on large aircraft which have very large primary control surfaces. The pilot manually moves the booster tab, and, in turn, it moves the primary surface.

2-31. *Spoilers.* Spoilers are of several different types. In effect, they momentarily destroy or interrupt a part of the lift pattern on a wing. Figure 7 shows the action of one type of spoiler.

2-32. This spoiler consists of a hinged flap 4 inches wide and about 4 feet long. It is recessed into the upper chamber of the wing (see fig. 4). In the top part of figure 7, the spoiler is not used. The flow of air over the wing is smooth and uninterrupted, and the full lifting power of the wing is realized. However, assume that a gust of air has caused the *left* wing to go down. The automatic flight control system instantly sends out a signal for the spoiler on the *right* wing to rise. By this action, the lift of the *right* wing is "spoiled" by the turbulence created by the spoiler. The right wing will begin to drop. (See bottom part of fig. 7.) Since the spoiler on the *left* wing is still recessed, the lift on that wing is now greater. This results in the left moving itself up to normal level flight. While this is going on, the right wing spoiler moves back to the recessed position.

2-33. An extended spoiler causes drag on one wing which may cause the aircraft to yaw. Therefore, when the spoiler extends, the rudder may be actuated at the same time to prevent yaw.

2-34. *Speed brakes.* These are used to increase drag to slow the aircraft and reduce landing distance. Several types of speed brakes are in use. The principle of operation is the same for combination or independent systems. Some aircraft use a combinination spoiler speed brake system. On others, the systems are independent of each other. When the spoilers are

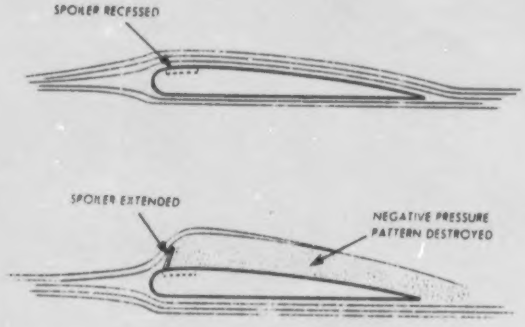


Figure 7. Action of spoilers.

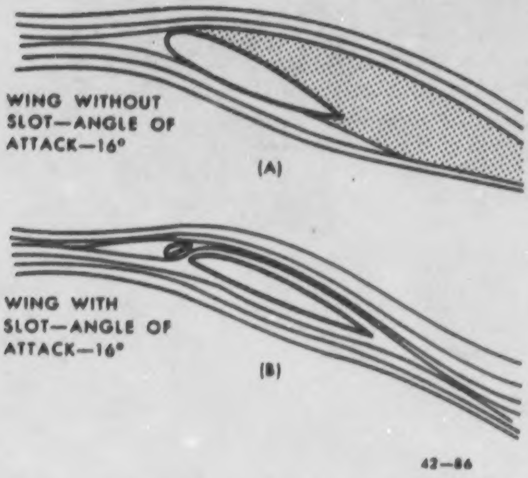

WING WITHOUT SLOT—ANGLE OF ATTACK—16°
(A)
WING WITH SLOT—ANGLE OF ATTACK—16°
(B)
42—86

Figure 8. Leading edge slot.

used as speed brakes, both sides will rise together. Some of these combination systems also allow the speed brake to be raised in various degrees. Fighter aircraft often use another type. Usually, this is just a large spoiler extended from the lower fuselage area.

2-35. *Slots.* The slot is basically a high lift device and is located along the leading edge of a wing. Refer to figure 8 and notice that view A shows a wing without slots. In view B, we have the same wing shown with slots. With the use of slots, the angle could be increased by 8° or 10°. Slots allow air to flow between them and the wing. This path causes the air to follow the camber in a laminar flow for a longer period. This guided flow prevents turbulence from destroying the negative pressure pattern. Slots are a valuable device for increasing lateral stability. Therefore, they are used with very slow flying reconnaissance aircraft or when landing high-speed aircraft. Most slot devices are retractable.

2-36. *Wing flaps.* The wing flap is a dual-purpose control, used to increase lift and also used to increase drag. Wing flaps are located under the trailing edge of the wings. Normally, about 25 percent flaps down is used for takeoff and full down flaps are used for landing. The increase of lift and drag means a slower landing speed and a steeper gliding angle.

2-37. Besides the simple flap, there is the split flap consisting of a hinged section of only the lower chamber. The upper chamber remains stationary as part of the wing structure while the lower section drops.

2-38. The most efficient type of flap is the Fowler flap. In this type, the flap moves down and slides aft on a track at the same time. This type is more effective, because it increases wing camber.

2-39. The flight control surfaces have to be attached to larger structural units if they are to control the aircraft's flight. We should now direct our attention to these larger components. We also want to know something about their construction.

3. Aircraft Construction and Identification

3-1. The parts of an aircraft which perform a certain function or related functions make up the structural units. Structures will vary a great deal according to the size and purpose of the aircraft. There are certain basic units common to most aircraft. These units are the fuselage, wings, stabilizers, control surfaces, landing gear, and nacelles. Stabilizers, the stationary tail surfaces, and the control surfaces are constructed much like the wings but are smaller. Therefore, we will not discuss them individually, but we'll cover the fuselage, wings, and landing gear.

3-2. **Fuselage.** This is the central body of the aircraft which contains compartments for the crew, passengers, cargo, and operating equipment. The fuselage also supports other units such as the wings and stabilizers. By referring to figure 9, you can see how the fuselage is constructed. The main support members running force and aft are longerons. Formers are used to give the fuselage shape and are interconnected by stringers. To separate the various compartments and also add to structural support, bulkheads are installed.

3-3. **Wings.** The wing is an airfoil designed to create most of the lift required for flight. In some cases, it also provides attach points for engines and landing gear. The wings are subjected to bending and twisting forces during

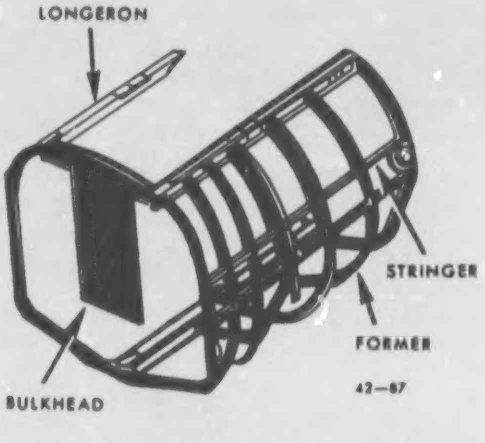


Figure 9. Fuselage construction.

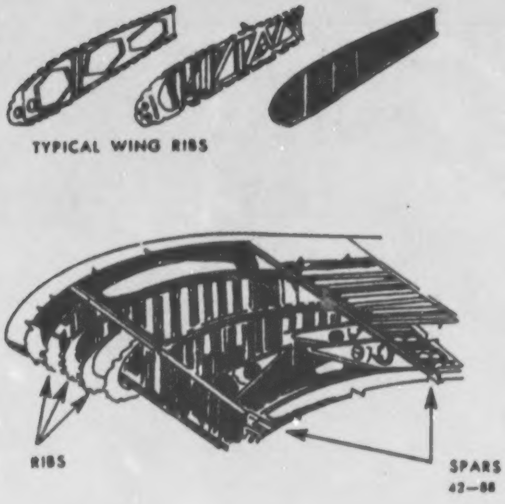


Figure 10. Wing construction.

flight and, therefore, must be strong. The backbone of the wing is the spar (or spars). Figure 10 shows the spar(s) as a long beam running spanwise (lengthwise) of the wing. The spars are tapered to conform to the shape of the wing. Fittings on the large end of the spar are used to attach it to the fuselage. Wing ribs are fastened to the spars to give the wing its shape. They also transfer the wing load from the covering to the spars.

3-4. **Landing Gear.** The landing gear is either fixed or retractable. The gear consists of the main wheels, a tailwheel or nosewheel, and the supporting struts. The landing gear causes drag during flight and, therefore, reduces airspeed. For this reason, the fixed type is used only on small, slow flying aircraft. The retractable type landing gear is drawn up into the wings or fuselage during flight. In the retracted position, the wheels and struts do not cause any drag. Therefore, the speed and range of the aircraft are increased. There are three basic types of retractable landing gear: the conventional, tricycle, and bicycle. The conventional type received its name in the early days of flight. It consists of two main gear and a tailwheel. The tricycle type is similar to the conventional type except that it has a nosegear instead of a tailwheel. The tricycle version is the most widely used of the three types. An aircraft with a bicycle type landing gear has main gear near the nose and tail sections of the fuselage. Small gear toward the wingtips balance the aircraft on the ground.

3-5. **Nacelles.** In multiengine aircraft, each engine or powerplant is inclosed in a structure called a nacelle. The nacelle provides shelter for the powerplants and accessories. It is streamlined to prevent drag. In the case of single-engine aircraft, the powerplant is mounted in the fuselage.

3-6. From what you have read about the major structural units, you may conclude that aircraft can be designed in a variety of patterns. This is true; the intended function of the aircraft determines its design. This brings up a need for a system to identify the various types. The Air Force has such a system, and it is our next subject for study. The last part of this section will present another system. This is a system of index stations designed to pinpoint specific locations in the aircraft.

4. Aircraft Types, Distinguishing Characteristics, and Designators

4-1. There usually are a number of different aircraft existing within a type at any one time. Yet, because all aircraft of one type have a specific function to perform, they have similar characteristics. Also, the identifying designators are intended to emphasize such grouping.

4-2. **Aircraft Types.** Military aircraft are grouped according to the basic mission for which they were designed, such as bomber, cargo, fighter, and trainer. Bombers are usually large multiengine aircraft so that they can carry a heavy bomb load long distances. Fighter aircraft are usually smaller, faster aircraft with one or two engines. They are used to intercept and destroy another aircraft or missile or are used for ground support missions.

4-3. Cargo or cargo/transport aircraft are usually large, multiengined aircraft designed for carrying cargo or passengers. Some cargo aircraft carry cargo and passengers at the same time. Others can be quickly converted from one to the other.

4-4. Trainer aircraft, on the other hand, are usually small aircraft with one or two engines. Pilot training aircraft have only two crew positions—one for the student and one for the instructor-pilot.

4-5. **Distinguishing Characteristics.** The different models of aircraft can be identified by their differences in appearance. Refer to the drawings of aircraft in figure 11 as we discuss these differences in the following paragraphs.

4-6. The wing is one of the major identifying characteristics. Notice such things as whether or not the wing is straight (F−104C), swept-back (B−52G, C−135B, C−141A, and F−4C), or delta (triangular shaped) (F−106A). The position of the wing on the fuselage is important for identification; for example, note the high wing on the B−52G

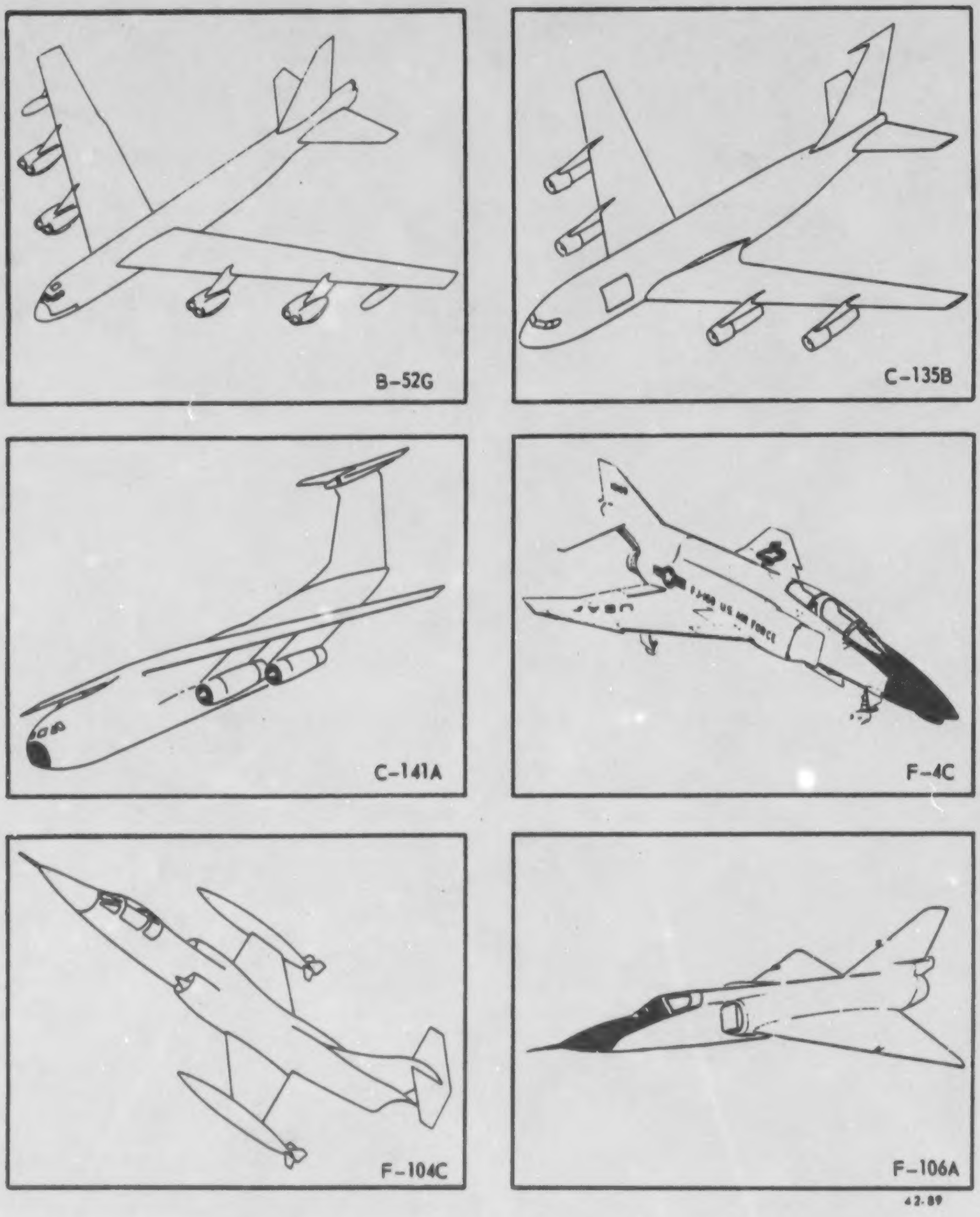


Figure 11. Aircraft identification.

and C–141A or the low wing on the C–135B and F–4C. Another wing characteristic that is helpful in connection with aircraft identification is its dihedral (the slant of the wing from root to tip). The C–135B has upward dihedral, and the B–52G and F–104C have downward (or negative) dihedral. Note the downward dihedral of the horizontal stabilizer of the F–4C and the upward dihedral of the F–4C wingtips.

4-7. Another characteristic used in aircraft identification is the engine. Engines are mounted in single pods as on the C-135B and C-141A, and in dual pods as on the B-52G. In fighter aircraft, they may be within the fuselage. Other aircraft (not illustrated) have engines mounted in the wings (B-57), on the wings (C-123), or on the aft fuselage (C-140A). Of course, the type of engine (reciprocating, turboprop, turbojet, or turbofan) is helpful in identification.

4-8. The empennage or tail assembly is usually an aid in the identification of aircraft. Note the "T" tail of the F-104C and the C-141A. Also, note the distinctive empennage of the F-4C with the extreme downward dihedral of the horizontal stabilizer (called a stabilator on the F-4C). The F-106A delta wing also serves the additional purpose of horizontal stabilizer. In addition, notice the extreme sweepback of the vertical stabilizer with its squared-off tip. Almost everyone will remember the triple vertical stabilizer of the C-121A Constellation (not pictured).

4-9. The fuselage of an aircraft also has distinguishing characteristics, particularly in the cockpit area. Notice in figure 11 the inclosed cockpits of the B-52G, C-135B, and C-141A; the bubble canopies of the F-4C and F-104C; and the sharp-pointed windshield of the F-106A.

4-10. **System of Designation.** All USAF aircraft are designated as to mission or type, model, and series by a combination of letters and numerals. The Secretary of Defense set up a common system of designation for all Department of Defense aircraft in July 1962.

4-11. *Numbering system.* The mission or type is represented by a single letter. The basic mission or type symbol is separated from the following model number by a dash. The letters and missions or types they represent are as follows:

A—Attack
B—Bomber
C—Cargo/Transport
E—Special electronic installation
F—Fighter
H—Helicopter
K—Tanker
O—Observation
P—Patrol
R—Reconnaissance
S—Antisubmarine
T—Trainer
U—Utility
V—VTOL and STOL (vertical and short takeoff and land)
X—Research
Z—Airship

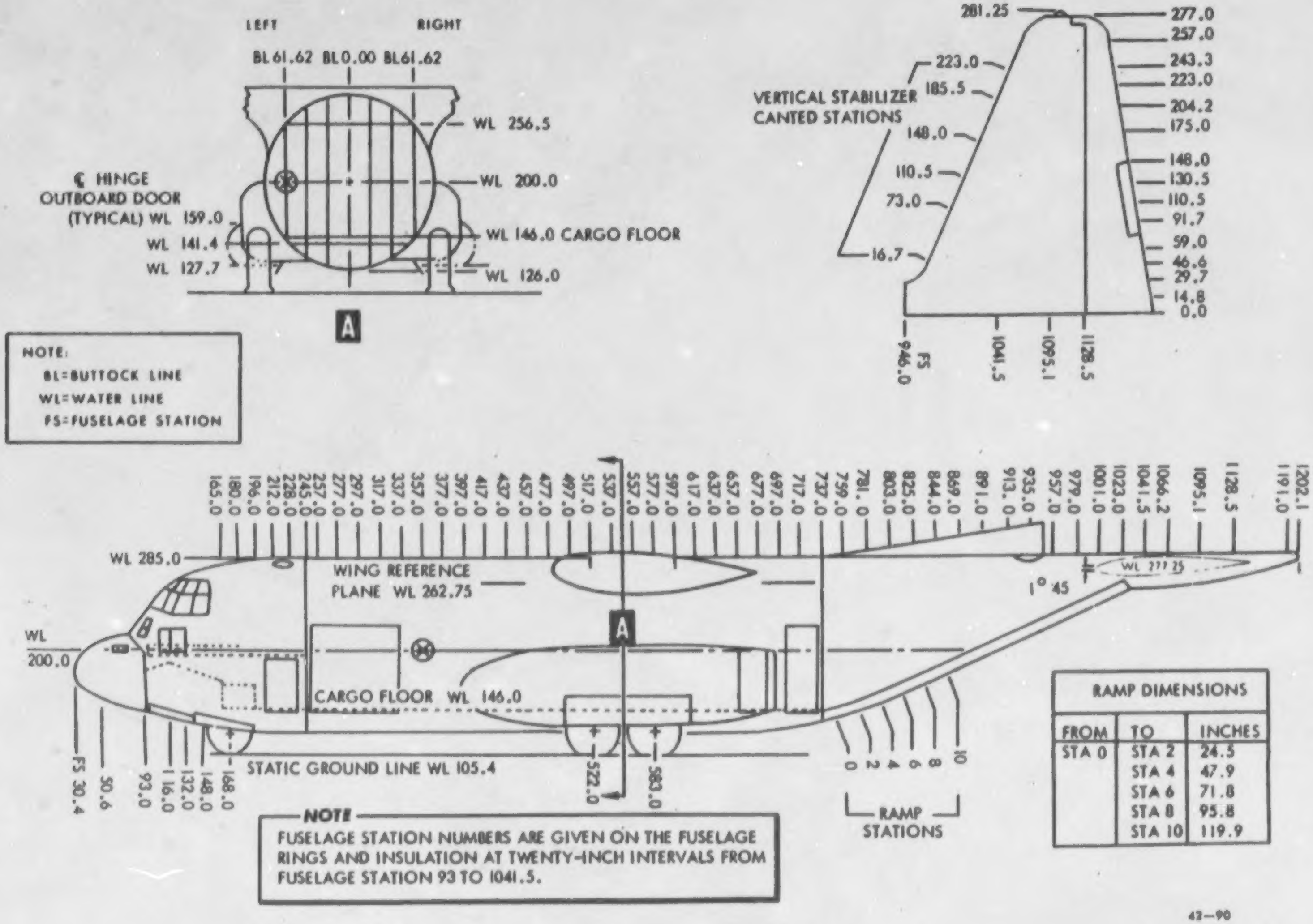
4-12. The second digit in the aircraft designator is the model number. A new aircraft is assigned the next consecutive model number within its basic mission/type. For example, the Air Force has a cargo aircraft designated the C-9A (this is a modified civilian DC-9 jet hospital); therefore, the next cargo aircraft will be designated C-10A whether it is built for the Air Force, Navy, Army, or all. So, when a new aircraft is *planned*, it will be assigned the next consecutive number for that type; yet, you may never see that aircraft on the flight line. The reason you don't see it is that not every aircraft designed becomes operational.

4-13. The series symbol is a letter which follows the model number. The first series of an aircraft model is always "A." Series changes of the same model are indicated by a new series letter. The series letters are assigned in alphabetical order, except for "I" and "O," which are not used to avoid confusion with the numbers 1 (one) and 0 (zero). Major differences in basic design require a change in the aircraft's series symbol. *Example:* The C-135A uses a conventional jet engine and the C-135B uses a turbofan jet.

4-14. Sometimes a basic aircraft is modified to perform a different mission from the original design mission. When this occurs, a modified *mission symbol* is added as a prefix. For example, the reconnaissance version of the F-4C is designated the RF-4C, and the tanker version of the C-135A is the KC-135A. The modified mission symbols, with an example of the use of each, are as follows:

A—Attack (AF-1E).
C—Cargo/Transport (CH-21C).
D—Director (DT-33A).
E—Special electronic installation (EB-47H).
H—Search/Rescue (HC-130B).
K—Tanker (KC-135A).
L—Cold weather (LC-130F).
M—Missile carrier (MF-3B).
Q—Drone (QB-47E).
R—Reconnaissance (RF-4C).
S—Antisubmarine (SH-34J).
T—Trainer (TF-102A).
U—Utility (UH-13T).
V—Staff (VC-137A).
W—Weather (WB-47E).

4-15. In addition to the modified mission and basic mission and type symbols, a *status* prefix symbol may be used. This is to indicate an aircraft that is being used for experimentation and special or service test. This symbol is always a prefix to the modified mission or basic mission/type symbols. It cannot be confused with a modified mission symbol, for the status prefix symbol uses a different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RIGHT
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BL61.62
WL 256.5
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℄ HINGE
OUTBOARD DOOR
(TYPICAL) WL 159.0
WL 141.4
WL 127.7
WL 146.0 CARGO FLOOR
WL 126.0
A
VERTICAL STABILIZER
CANTED STATIONS
281.25
223.0
185.5
148.0
110.5
73.0
16.7
277.0
257.0
243.3
223.0
204.2
175.0
148.0
130.5
110.5
91.7
59.0
46.6
29.7
14.8
0.0
FS 946.0
1041.5
1095.1
1128.5
WL 285.0
WING REFERENCE
PLANE WL 262.75
WL 200.0
CARGO FLOOR WL 146.0
STATIC GROUND LINE WL 105.4
1° 45
WL 277.25
165.0
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196.0
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RAMP
STATIONS
42—90

NOTE:
BL=BUTTOCK LINE
WL=WATER LINE
FS=FUSELAGE STATION

NOTE
FUSELAGE STATION NUMBERS ARE GIVEN ON THE FUSELAGE RINGS AND INSULATION AT TWENTY-INCH INTERVALS FROM FUSELAGE STATION 93 TO 1041.5.

RAMP DIMENSIONS

FROM	TO	INCHES
STA 0	STA 2	24.5
	STA 4	47.9
	STA 6	71.8
	STA 8	95.8
	STA 10	119.9

Figure 12. Airplane stations.

set of letters. The status prefix symbols with some examples are as follows:

G—Permanently grounded (GF–100A).
J—Special test, temporary.
N—Special test, permanent (NF–104A).
X—Experimental (XB–70A).
Y—Prototype (YAT–28D).
Z—Planning.

4-16. Now we have learned the system of designation for aircraft. Next, let's take an aircraft and learn how to locate specific units on it.

4-17. *Locating aircraft units.* With the increase in size and complexity of aircraft, the mechanic's job could be very difficult. He must become familiar with more systems and units. So to make your job easier, the aircraft use a system of imaginary lines. These are guidelines to help you locate the components. They are called water lines, buttock lines, and station numbers. Figure 12 shows these lines and stations.

4-18. First, we must have a fixed reference line as a starting point. We might think that the nose of the aircraft would be a good place for a fixed reference. But suppose, as sometimes happens, the nose is entended several feet to house some new equipment. Then there would be units on both sides of our reference line. This is not good because we would have to use positive and negative station numbers. Therefore, some point several feet in front of the nose is used as a reference. This is called station 0. Going back from station 0, the fuselage is laid out in more stations. Notice in figure 12 that the nose of the aircraft is at station 30.4; this leaves room for modifications. Station numbers are given in inches.

4-19. Next, look at view A of figure 12, and you can see that we have vertical lines called buttock lines. Buttock lines (BL) 0 will be in the center with a series of buttock lines parallel to it going right and left. To complete our location, we need one more reference line.

4-20. Water lines (WL) run horizontally and will complete the location of the unit. Water lines are similar to station numbers, since water line 0 is somewhere below the aircraft. Notice in figure 12 that the static ground line is WL 105.4, so we will work from that point to the top of the fuselage. An example of a location would be: station 357, BL 61.62 L, WL 200. This location is shown in figure 12 by a circle with an X in it. It appears in both the side and end views.

4-21. Wings, nacelles, and stabilizers use station numbers, buttock lines, and water lines as the fuselage does. To aid in location of wing components, the engines on multiengine aircraft are numbered from left to right (eng. No. 1, No. 2, etc.). Locations of units on the engine are like on a clock, such as No. 2 engine, 3 o'clock position. All aircraft and engine locations are given as viewed from the rear of the aircraft looking forward.

4-22. Aircraft that carry fuel in the wings without bladders or internal tanks are called wet wing aircraft. This type uses the skin of the wing to contain the fuel. However, they will have dry bays behind the engines to house components. So, we could locate a unit as being in the No. 3 engine dry bay forward of the center spar. This system of location is a great help in locating components.

CHAPTER 2

Principles of Electricity

DURING THE early days of aircraft hydraulic systems, the need for understanding electricity was limited. At that time, we used engine-driven pumps, hand pumps, and manually operated valves. Now, however, the modern aircraft hydraulic systems are almost entirely electrically controlled and hydraulically actuated. Remote units can be actuated almost instantly by movement of an electrical switch. The switch energizes a circuit which initiates the hydraulic operation of the unit. Thus, the system operator needs to know little more than when to flip a certain switch.

2. This is not true of the pneudraulic mechanic. He must be able to locate and repair troubles in hydraulic systems. But, he must first determine if it is an electrical or a hydraulic failure. To do this, he must have at least a fundamental knowledge of electricity. This chapter will help you to develop your electrical knowledge. We will study symbols, types of circuits, and the relationship of current, voltage, and resistance. Next, we will discuss common circuitry troubles. To help in locating circuit problems, we will go into the use of the volt-ohm-milliamter.

5. Electrical Fundamentals

5-1. No doubt you have used electricity many thousands of times—in lights, fans, radios, razors, and other devices. When you turned on the switch, chances are that the appliance worked. There are two reasons that it did: (1) Closing the switch completed a conductor path from the electricity source, to the unit, and back to the source. (2) There were countless free electrons in the conductor moving through the conductor (current). These electrons were pushed and pulled respectively by the − and + poles of the source. The source may be a battery, generator, or alternator.

5-2. Electrons are tiny negatively charged particles and are parts of atoms. All atoms are made up of electrons, protons (positively charged particles), and neutrons (neutral particles). Protons and neutrons make up the nucleus or core of the atom. The electrons orbit around the nucleus like the planets orbit around the sun. Every natural substance is made up of identically built atoms. No *two* substances are made up of the *same* structural atoms. Electrons are in constant motion. In some substances, the outermost electrons are loosely held. The attraction and repulsion of the two poles of a power source moves the electrons. They cause one loosely held electron of an atom to jump to the next atom. Now this second atom is overloaded by one electron. Attraction and repulsion then causes an electron of the gainer atom to jump to the third atom. And—so on and on. This flow of electrons is called current.

5-3. The number of free electrons varies with the substance. Some substances have a comparatively large number of free electrons. Current can flow through them with ease. Such substances are called conductors. In general, metals and their alloys are good conductors. Copper, for example, is the common conductor used in aircraft to conduct electricity in the various systems.

5-4. Other substances contain only a small proportion of free electrons and offer considerable resistance to the transfer of electrons. These substances are called insulators. They are used to insulate conductors and keep the electric current from flowing in undesired paths. Some common insulators are mica, glass, rubber, bakelite, and plastics.

5-5. **Electrical Symbols.** Every science has its own language—oral and written. The field of electricity is no different. We communicate electrically by means of wiring diagrams. A wiring diagram tells how a circuit is built and how it operates. It shows all the wires or conductors used, the components, and how everything is connected. Wires are represented on the drawing by straight lines. Switches, solenoids, circuit breakers, etc., are not drawn out, but a symbol for each is used. Figure 13 shows these symbols, with names, that might appear on a pneudraulic wiring diagram. You

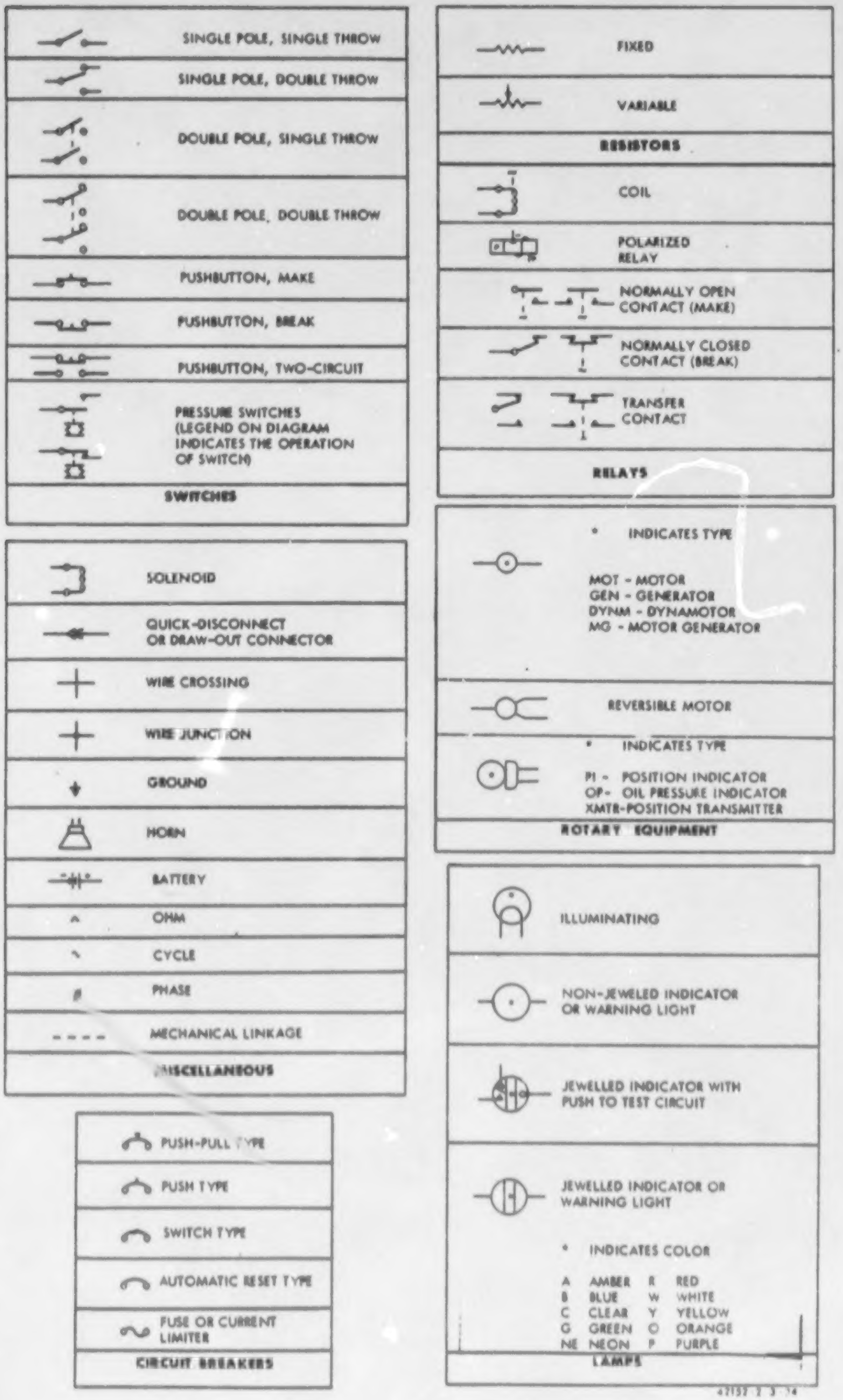
SINGLE POLE, SINGLE THROW
SINGLE POLE, DOUBLE THROW
DOUBLE POLE, SINGLE THROW
DOUBLE POLE, DOUBLE THROW
PUSHBUTTON, MAKE
PUSHBUTTON, BREAK
PUSHBUTTON, TWO-CIRCUIT
PRESSURE SWITCHES (LEGEND ON DIAGRAM INDICATES THE OPERATION OF SWITCH)
SWITCHES
SOLENOID
QUICK-DISCONNECT OR DRAW-OUT CONNECTOR
WIRE CROSSING
WIRE JUNCTION
GROUND
HORN
BATTERY
OHM
CYCLE
PHASE
MECHANICAL LINKAGE
MISCELLANEOUS
PUSH-PULL TYPE
PUSH TYPE
SWITCH TYPE
AUTOMATIC RESET TYPE
FUSE OR CURRENT LIMITER
CIRCUIT BREAKERS
FIXED
VARIABLE
RESISTORS
COIL
POLARIZED RELAY
NORMALLY OPEN CONTACT (MAKE)
NORMALLY CLOSED CONTACT (BREAK)
TRANSFER CONTACT
RELAYS
* INDICATES TYPE
MOT - MOTOR
GEN - GENERATOR
DYNM - DYNAMOTOR
MG - MOTOR GENERATOR
REVERSIBLE MOTOR
* INDICATES TYPE
PI - POSITION INDICATOR
OP- OIL PRESSURE INDICATOR
XMTR-POSITION TRANSMITTER
ROTARY EQUIPMENT
ILLUMINATING
NON-JEWELED INDICATOR OR WARNING LIGHT
JEWELLED INDICATOR WITH PUSH TO TEST CIRCUIT
JEWELLED INDICATOR OR WARNING LIGHT
* INDICATES COLOR
A AMBER R RED
B BLUE W WHITE
C CLEAR Y YELLOW
G GREEN O ORANGE
NE NEON P PURPLE
LAMPS
42152 2 3 74

Figure 13 Electrical symbols

need to know these to be able to read even a simple pneudraulic wiring diagram. Refer to them often.

5-6. **Electrical Circuits.** The electricity used to operate devices in an aircraft flows in a circuit when the switch is closed. This flow has a number of characteristics that we should know about. We will discuss these in the following paragraphs.

5-7. Electric current that flows only in one direction through a conductor is called direct current (dc). Direct current is produced by a battery or by a generator. Most pneudraulic control circuits are dc.

5-8. The electricity you use in your home or shop or for your power tools is alternating current (ac). In commercial ac electricity, the direction of current flow changes 120 times per second. It alternates at a 60-hertz rate (a hertz is 1 cycle per second). Modern aircraft use ac electricity of 115 to 400 hertz. It is seldom used in pneudraulic systems. Ac is produced by an alternator, never by a battery.

5-9. A complete electrical circuit is a path through which electrons can flow. An electrical circuit is shown in figure 14. We will relate this to a hydraulic system. It consists of a battery (accumulator) which stores electrical pressure, two conductors (pressure and return lines), a fuse (relief valve) for protection, a switch (control valve), and a lamp (actuating unit). In figure 14, we show only a simple system. There are many other units used in electrical systems. We might point out that a generator serves the electrical system in the same basic manner as a hydraulic pump.

5-10. **Electrical Terms.** Before going too deeply into electrical circuits, we must be sure we understand certain terms. We shall explain several.

5-11. *Electromotive force.* The pressure that forces free electrons through the conductors and electrical devices is called electromotive force. Other names for this pressure are *voltage* or *difference of potential*. On aircraft, electromotive force is supplied by generators and alternators (which convert mechanical energy into electrical energy). The unit of measurement of electromotive force is called a *volt* and is measured by a *voltmeter*. Most of the present aircraft have 28-volt dc electrical systems.

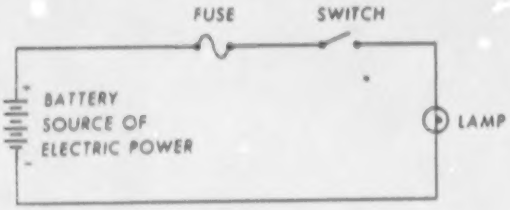

Figure 14. An electrical circuit.

5-12. *Voltage drop.* This is the amount of voltage (pressure) used to drive the current through a unit (resistance) in the circuit. For example, assume that the battery in figure 14 puts out 6 volts; also, that the switch is closed and we will disregard the tiny resistance of the fuse, wire, and switch. We say that we have a 6-volt battery because the difference of potential (see paragraph 5-11) between its two poles is 6 volts. On one side of the lamp there are 6 volts of force and on the other are 0 volts. All difference of potential is used up in the exterior circuit between the battery poles. So, we can say that there is a 6-volt voltage drop across the lamp resistance. This lights the lamp fully.

5-13. Now, let's put two of the same size lamps in the circuit in *series* (one after the other). The same voltage is to push the same flow of electrons through both lamps. Will both lamps burn brightly? No, because we saw that this specific size lamp requires a 6-volt drop through it to be fully lit. Does this mean that the second lamp will have no voltage left to drop (consume)? Actually, this is what will happen: Since both lamps are the same size, each will have a 3-volt drop across it. This will probably produce only a dim glow in each. To make both lamps burn brightly, two smaller candlepower lamps must be used. Each of the smaller lamps will burn brightly with a 3-volt drop across (through) them.

5-14. On the basis of what we have learned about voltage drop, we can make these statements: The voltage drop in a working circuit is equal to the voltage applied to the circuit. Also, the total voltage drop in a working circuit is equal to the sum of the individual drops in series.

5-15. *Current.* The flow of electrons is called electrical current. The unit of measurement of current is called an ampere and is measured by an ammeter.

5-16. Before the discovery of the electron, it was assumed that the flow of current was from positive to negative. This concept was known as the conventional direction of current flow. Scientists now agree that the electrons in motion are the current, and that current flows from negative to positive. This is known as the electron theory direction of current flow. The electron theory method is the recognized method of current flow today.

5-17. *Resistance.* The opposition to the flow of current offered by the conductors within a circuit is called *resistance*. The amount of resistance offered by a conductor depends upon: (1) the material of which the conductor is made—some metals conduct better than others; (2) the length of the conductor—resistance increases as the length increases; (3) the cross-sectional area—as the thickness of the conductor increases its resistance decreases; and (4) the temperature of the conductor—in *most* conductors the resistance increases as the temperature increases. However, in a few cases the temperature has an opposite effect. The unit of measurement of resistance is called an ohm. The instrument by which resistance is measured is called an ohmmeter.

5-18. *Ohm's law.* There is a definite relationship between the voltage, current, and resistance of any electrical circuit. If the voltage is increased, the current increases proportionately. This relationship is known as Ohm's law (so called in honor of George Ohm who first discovered it) and is generally stated as follows: *The current in a circuit is equal to the voltage divided by the resistance.* Mathematically it is written as:

$$I = \frac{E}{R} \quad \text{or} \quad \text{current} = \frac{\text{voltage}}{\text{resistance}}$$

5-19. Remember the triangle formula we had in Chapter 1 of Volume 2 for basic hydraulics ($F = A \times P$)? We have a similar triangle for electricity. Figure 15 illustrates the Ohm's law formula. I stands for current in amperes, E for voltage in volts, and R for resistance in ohms. Thus, if the source of voltage in a circuit is a 6-volt battery and the electrical device is a bulb having 3 ohms of resistance, the current will be $\frac{6}{3}$, or 2 amperes ($I = \frac{E}{R}$).

5-20. You can find the voltage across a component of a circuit if you know its resistance and the current through it. *Example:* if you know that the current through a lamp is 2 amperes and resistance of the lamp is 3 ohms, you use the formula $E = I \times R$. You find that the voltage across it must be 3×2, or 6 volts.

5-21. You can find the resistance of any circuit component if you know the voltage across it and the current through it. Suppose you know that the voltage across a lamp is 6 volts, and the current through it is 2 amperes. You can find its resistance by using the formula $R = \frac{E}{I}$. The resistance, then, is $\frac{6}{2}$, or 3 ohms.

5-22. With the formula in figure 15 and two known quantities (current, voltage, or resistance), you can figure out the remaining unknown quantity. An easy aid in remembering the three relationships is the triangle formula. Place your finger over the quantity you don't know. The positions of the other two tell you how to find it. If one is above the other, divide the one above by the one below to find the unknown quantity. If they are alongside each other, multiply them together to find the unknown quantity.

5-23. **Types of Circuits.** Electrical circuits can be divided into three general classifications: series, parallel, and series-parallel circuits. Most that we use will be either parallel or series-parallel.

5-24. *Series circuits.* A series circuit is one in which there is only one path which the voltage can force the current. The circuit shown in figure 16 consists of three resistances and a battery, connected to form a series circuit. Since there is but one path for the current, the amount of current is the same throughout the circuit. If a thousand electrons leave the negative battery plate, a thousand must return to the positive plate. The *total* resistance is equal to the *sum* of the resistances in the circuit. If one device (motor or lamp) in a series circuit burns out, there is no longer a complete path for the current. As a result, no current will flow, and the other devices in the circuit will not operate. The order in which components are connected in series does not affect the current of that circuit. With current through a resistance, there is voltage drop across it equal to $I \times R$. Each time current passes through a resistance it reduces the remaining voltage to the remaining resistors. The potential difference, if measured by a voltmeter, between the two ends of a resistor is the voltage drop. *Total* voltage drop is the sum of the voltage drops in the circuit.

5-25. Here is how you use Ohm's law in solving a series circuit problem:

Problem:

In the series circuit diagram shown in figure 16, three resistances are connected in series across a 24-volt power source. A voltmeter across each resistance has determined its voltage drop. An ammeter placed in series in the circuit has determined the current that is flowing at that point.

Find:

a. The total voltage drop.
b. The total current.
c. The resistance of each unit and the total resistance.

Given:

We can read the following facts from the figure:

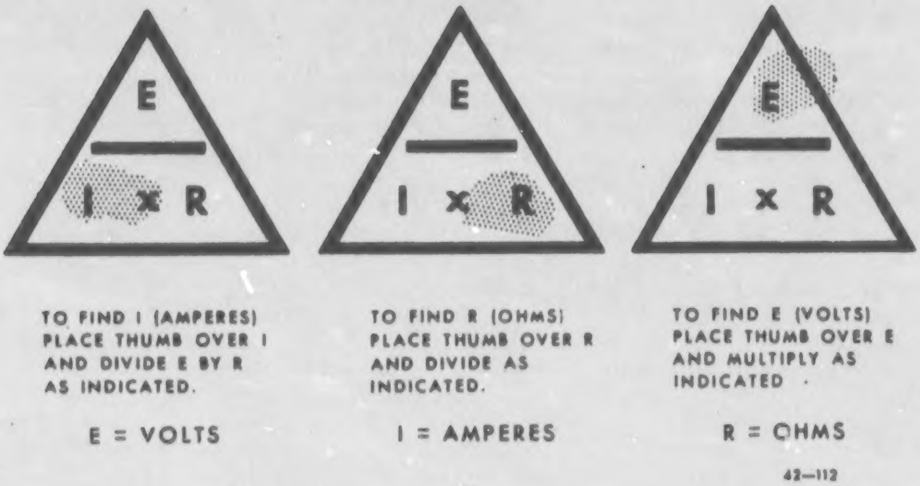
E
I x R
E
I x R
E
I x R
TO FIND I (AMPERES) PLACE THUMB OVER I AND DIVIDE E BY R AS INDICATED.
TO FIND R (OHMS) PLACE THUMB OVER R AND DIVIDE AS INDICATED.
TO FIND E (VOLTS) PLACE THUMB OVER E AND MULTIPLY AS INDICATED.
E = VOLTS
I = AMPERES
R = OHMS
42—112

Figure 15. Ohm's law formula.

a. The battery puts out 24 volts.

b. The ammeter reads 4 amps.

c. The voltmeter reads an 8-volt difference of potential across R_1, 12 volts across R_2, and 4 volts across R_3.

Solution:

a. The total voltage drop $E_T = 8 + 12 + 4 = 24$ volts.

b. The current in a series circuit is the same in all parts of the circuit and is equal to 4 amperes. It is 4 amps through each resistor.

c. Resistance of each unit is equal to voltage divided by the current for that unit.

$$R_1 = \frac{E_1}{I} = \frac{8}{4} = 2 \text{ ohms}$$

$$R_2 = \frac{E_2}{I} = \frac{12}{4} = 3 \text{ ohms}$$

$$R_3 = \frac{E_3}{I} = \frac{4}{4} = 1 \text{ ohm}$$

The total resistance:

$$R_T = R_1 + R_2 + R_3 = 2 + 3 + 1 = 6 \text{ ohms}$$

Double check: $R_T = \frac{E_T}{I} = \frac{24}{4} = 6$ ohms

5-26. *Parallel circuits.* Most of the electrical devices in aircraft electrical systems are connected in parallel. In a parallel circuit, two or more paths are provided for current flow. The voltage drop across the devices in each parallel path is the same in all paths. Total current in this circuit is equal to the sum of the currents flowing in each path. Therefore, the total amount of current is greater than the current in any individual path. Total resistance of the entire circuit is less than the smallest resistance of any path. (By Ohm's law—the current is greater; therefore, the resistance must be less.) The more paths the current has to follow the less overall resistance to its flow there is.

5-27. Electrical devices are connected in parallel to allow them to be operated independently. If one device in a parallel circuit burns out, the others may still be operated. (One path is broken, but the others are still complete.)

5-28. Figure 17 consists of three lamps and a battery, connected to form a parallel circuit. We will use Ohm's law to solve a parallel circuit problem.

Problem:

The voltages and current for figure 17 were measured and found to be as indicated on the figure.

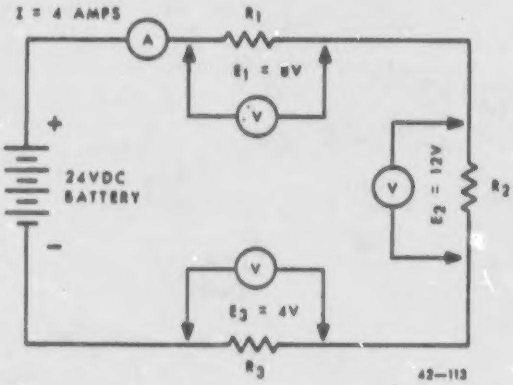
I = 4 AMPS
A
R1
E1 = 8V
V
+
24VDC BATTERY
-
V
E2 = 12V
R2
V
E3 = 4V
R3
42—113

Figure 16. Series circuit.

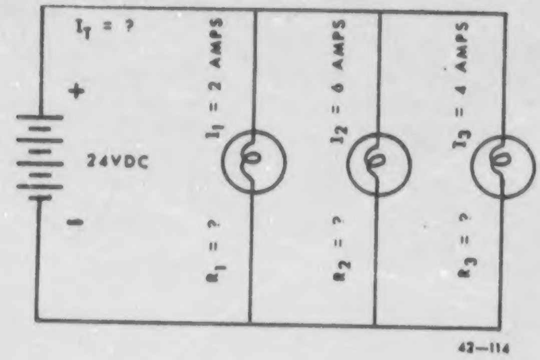

Figure 17. Parallel circuit.

Find:

a. The voltage drop across each lamp.
b. The total current.
c. The resistance of each lamp.
d. The total resistance.

Given:

We can read the following facts from the figure:

a. The battery delivers 24 volts.

b. Two amps of current flow through path 1, 6 amps flow through path 2, and 4 amps flow through path 3.

Solution:

a. The voltage drop in parallel circuits is the same across each path. In this circuit, it is 24 volts.

b. The total current (I_T) in a parallel circuit c, col. 2

$$I_T = I_1 + I_2 + I_3 = 2 + 6 + 4 = 12 \text{ amps}$$

c. Find the resistance of each lamp by dividing the voltage across the lamp by the current which flows through the lamp.

$$R_1 = \frac{E_1}{I_1} = \frac{24}{2} = 12 \text{ ohms}$$

$$R_2 = \frac{E_2}{I_2} = \frac{24}{6} = 4 \text{ ohms}$$

$$R_3 = \frac{E_3}{I_3} = \frac{24}{4} = 6 \text{ ohms}$$

d. The total resistance (*RT*) in a parallel circuit is equal to the voltage divided by the total current.

$$RT = \frac{E}{I_T} = \frac{24}{12} = 2 \text{ ohms}$$

This proves the statements made in paragraph 5-26 concerning parallel circuits: Total resistance (of the entire circuit) is less than the smallest resistance of any path.

5-29. *Series-parallel circuits*. In a series-parallel circuit, some units are in series and others in parallel. In the circuit shown in figure 18, the resistor is in series with the lights, but the lights are in parallel with each other.

5-30. To solve a series-parallel circuit problem, first convert it to a series circuit. To do this, substitute an equal resistance for the parallel resistances; then solve the series circuit. The solution of the following series-parallel circuit shows how this can be done.

Problem:

In the circuit shown in figure 18, a resistor is in series with four lamps in parallel with each other.

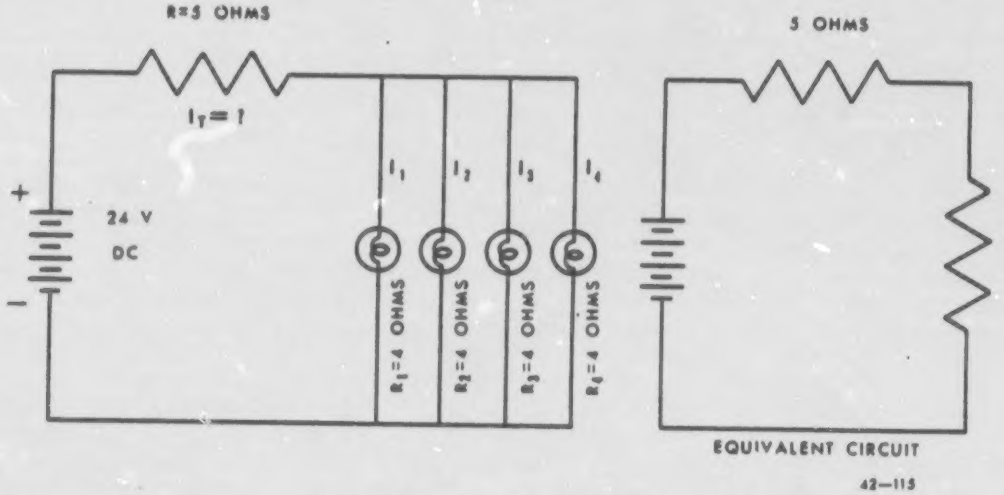

Figure 18. Series-parallel circuit.

Find:

The currents in the various parts of the circuit.

Given:

a. The battery delivers 24 volts.

b. The resistor is of 5 ohms.

c. Each of the 4 lamps has 4 ohms of resistance.

Solution:

a. The 4 lamps in parallel have equal resistance. Therefore, total resistance is equal to the resistance of one unit divided by the number of units.

b. Since the resistance of each lamp is 4 ohms, the resistance of the four lamps in parallel is 4/4, or 1 ohm.

c. Now, substitute a 1-ohm resistor for the four lamps. See the right-hand circuit in figure 18. Add the two resistances in series and you have 5 + 1, or 6 ohms total resistance.

d. The total current in the circuit is 4 amperes ($I = \frac{E}{R} = \frac{24}{6} = 4$).

e. Since the total current must flow through the resistor, the current through it is 4 amps.

f. The total current flow through all four lamps is 4 amps. Since all the lamps have equal resistance, the 4 amps of current will divide equally among them. This gives each lamp 1 amp of current.

5-31. **Method of Wiring.** In most aircraft electrical systems, single-wire circuits are used. That is, only one wire is used to connect an electrical device to the source of electromotive force. The circuit is completed back to the battery or generator through the metal structure of the airplane. In such circuits, the airplane structure is called ground, and the terminals connected to it are said to be grounded. Single-wire circuits remove the need for a second wire and thus save material and weight.

5-32. **Solenoids and Relays.** A characteristic of electricity is that it can produce a magnetic field around a conductor. This occurs when current is passed through a coil of wire. A coil concentrates the field built up around a wire. The strength of the magnetic field depends upon the number of turns of wire in the coil plus the amount of current passing through it. The magnetic field can be seen by placing a bar of iron partly into a coil of wire. When current is applied to the coil of wire, the bar is drawn in. While under the influence of the magnetic field, the iron bar will become a temporary magnet. It is this electromagnetic principle which operates solenoids and relays. In the *solenoid*, for example, an iron bar is held halfway out of the coil by a spring. When the coil is energized, the bar moves in rapidly. This action can be used to position hydraulic valves, operate switches, and perform other duties. The *relay* has a permanent fixed iron core to concentrate the magnetic field. When energized, the magnetism of the coil attracts a movable iron contactor. This action, in turn, closes a switch to complete a circuit or performs other duties. The reason for using a relay or solenoid is that a small wire and current flow can produce swift mechanical action. This action completes circuits involving larger wires and higher voltages and current in remote areas.

5-33. Up to this point, we have discussed direct current (dc). We will not go into alternating current (ac) because a pneudraulic man rarely comes into contact with ac circuits on aircraft. In the next section, the knowledge we have gained so far will be applied in a practical way. We will study electrical circuits, common circuit troubles, and how to locate and identify the troubles.

6. Circuitry Troubles

6-1. Many electrical systems have independently acting circuits within the system itself. All of these individual circuits must work properly, or the parent circuit will malfunction. For example, a parent circuit might control a sequence of operations performed by a mechanism. If one of the independent circuits fails, its operation in the sequence would be affected.

6-2. Most troubles which are apt to occur in any electrical circuit stem from three basic causes: open circuits, short circuits, and grounded circuits. First, let's examine these three basic causes of trouble. Then we'll briefly consider a few other troubles which you may encounter.

6-3. **Open Circuits.** If current is to flow in a circuit, two primary requirements must be fulfilled. There must be a difference in potential (voltage) and a complete path through which the electrons can move. Should one of the wires become broken, the circuit is interrupted. The movement of the electrons will cease. An incomplete circuit caused by a break in the wire is called an open circuit, or *open*. Another possibility is that one of the main conductors has pulled loose. In this case, no unit in that entire system would operate.

6-4. To learn how to locate an open in an electrical circuit, study figure 19. The circuit shown contains a lamp which is in series with a single-throw switch and a fuse. Section A of the figure shows the normal voltage reading between the various points of the circuit and ground. If the lamp fails to function, the circuit should be checked in progressive steps. Begin with either the source voltage *or* the last voltage reading. You may choose to work from the battery toward the lamp. Or, you may start from the lamp and work toward the battery. You will choose whichever method is easier. Section B of the figure shows that there is voltage at one connection of the fuse and not at the other. Since a fuse is a conductor, you should normally get the same reading at both ends. Obviously, you will conclude that the fuse is open. Section C of the figure shows voltage at one connection of the lamp, but no voltage at the other. This is normal if the lamp were burning. But, the lamp fails to light. The obvious conclusion is that the trouble lies within the lamp itself. The voltage is pushing no current through it.

6-5. In Section D of the figure, the lamp does not light. Yet the voltmeter shows there is full voltage going into the lamp. So far, everything looks normal. But in spite of the 24 volts in the lamp, it still won't light. So we check further and find 24 volts at the other side of the lamp. This is not normal because if the lamp lights, this reading is zero. This tells us that even though there is voltage or pressure in the lamp, there is *no voltage drop across it*. If there is no voltage drop across the lamp, is there a current flowing through it? No. If no current flows, no work is being done and the lamp filament is not heated. Obviously, there must be an open somewhere in the circuit. Since there is voltage above and through the lamp, the open must be beyond the lamp. It must be in the ground wire. Another voltmeter check farther down the ground wire proves our reasoning.

6-6. In figure 20, you find two lamps, R and G. They are wired in parallel so that they can be controlled by the use of a double-throw switch. With the switch in the OFF (center) position, there is no complete circuit. Neither lamp will operate. When the switch is moved to the BRIGHT position, a circuit is completed through the switch. It continues through both lamps and back to the battery. With the switch in this position, the only resistance in the circuit is that of the lamps. When the switch is in the DIM position, the circuit is completed through the lamps as before. However, this circuit has an additional resistor in series with the lamps. This added resistance causes the current flow to decrease because the total circuit resistance is greater. The lamps will burn with less brightness than before.

6-7. If one of the lamps operates and the other does not, what or where would you suspect the malfunction to be? In this case it was not necessary to check the complete circuit to find the broken wire. You know the part of the circuit up to point A is common to both lamps. That much of the circuit must be complete for either lamp to function. The place to begin checking the circuit, then, is beyond point A in the affected part of the circuit.

6-8. In circuits like the one illustrated in figure 20, use a voltmeter as an aid in locating the malfunction. The ground lead of the voltmeter should normally be connected to the metal structure of the aircraft. Move the positive terminal of the voltmeter from A to B to C in succession. By doing this, you will be able to check the continuity (continuousness) of wires AB and BC. If there is voltage at point B but none at point C, it indicates that wire BC is open.

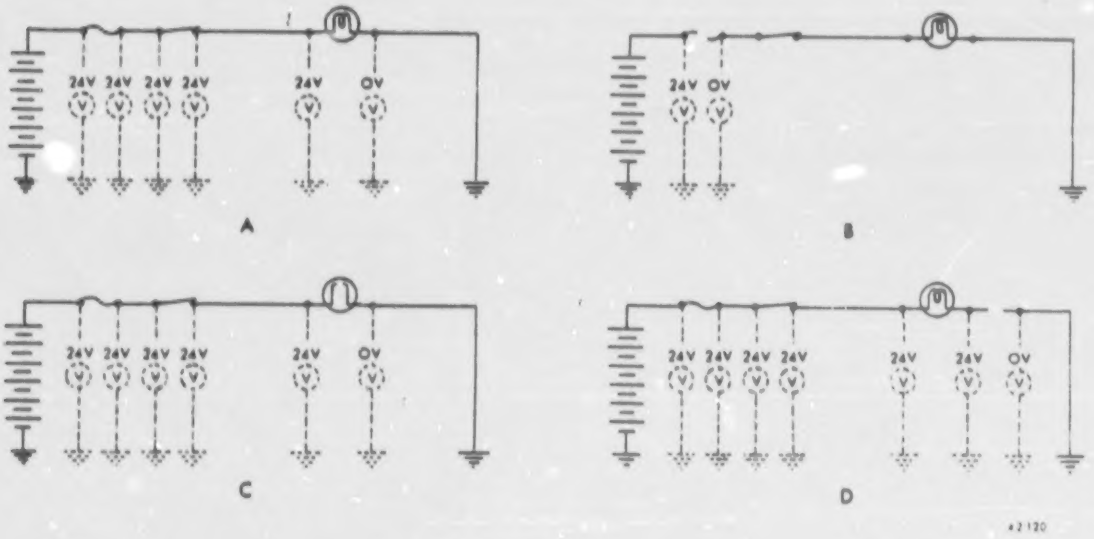

Figure 19. Troubleshooting an open circuit using a voltmeter

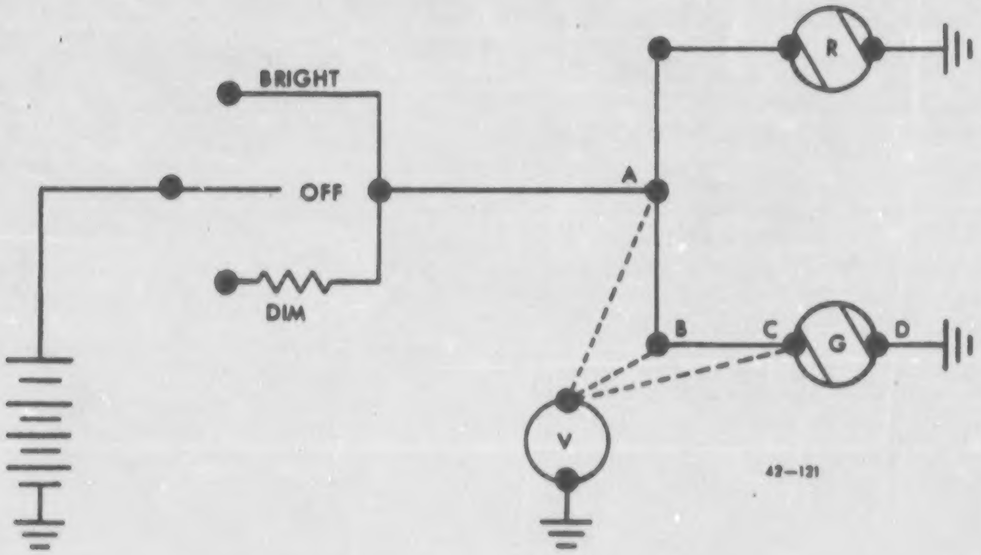

Figure 20. Troubleshooting a light circuit using a voltmeter.

6-9. You can make this same check with an ohmmeter, but you will have to take several additional steps. These are indicated in figure 21. The first step is to remove the electrical power from the circuit. This you do by placing the control switch in the OFF POSITION. Next, you open the junction of the wires at point A to prevent completion of the ohmmeter circuit through light R. Then, with one terminal of the ohmmeter grounded to the aircraft structure, you can check the continuity of the wires. We will proceed from point D toward the end of the disconnected wire at point A. There is a continuous circuit to ground from a check point if there is a low resistance on the ohmmeter. With the ohmmeter test lead moved to points C and B in succession, each reading should add a few ohms. If infinity (∞) is suddenly indicated on the meter, an open is the cause. Such a reading occuring when the test lead is at B indicates an open in line BC.

6-10. Often you can almost locate the open by studying the circuit diagram before checking. Suppose both lamps in figure 20 operate when the circuit control switch is in the BRIGHT position. Neither lamp operates when the switch is in the DIM position. If the lamps operate normally in the BRIGHT position, you can assume that the wires and bulbs are good. Through this process of elimination, you know that one of the remaining units is at fault. It must be the resistor, the wires that connect it to the circuit, or the switch. Now you have narrowed down the possibilities to one area by reasoning. Your next move is to locate the exact fault with a meter. By using your head, you eliminated a lot of random meterwork in the good circuits.

6-11. **Short Circuits.** The insulation specification for aircraft wiring is normally set to withstand 600 volts minimum. The greatest number of insulation troubles results from abrasion. Normally, the wiring arrangement allows no great amount of movement between wires. All possible points of chafing are covered with rubber or cork protectors. Despite these precautions, accidental contact between uninsulated lengths of conductors sometimes occurs. These accidental low-resistance circuits are known as short circuits. Short circuits often result in a peculiar cycle of events. *Example:* When you close the switch for one device, it operates normally, but other components or entire systems operate also. Every electrical circuit is protected in some way against an electrical overload. There is either a fuse or a circuit breaker near the power source. These devices will automatically open the circuit when it is overloaded by a short. A continuous short circuit between bare conductors might cause an electrical fire aboard the aircraft.

6-12. To find a short circuit, it is necessary to electrically isolate the suspected circuit from all others. This is best done by disconnecting each circuit at both ends, as shown in figure 22. In this figure there are two lamps, R and G; each is controlled by a separate switch. With the circuits electrically isolated, place an ohmmeter between the two disconnected sections. Normally, the resistance measured between two

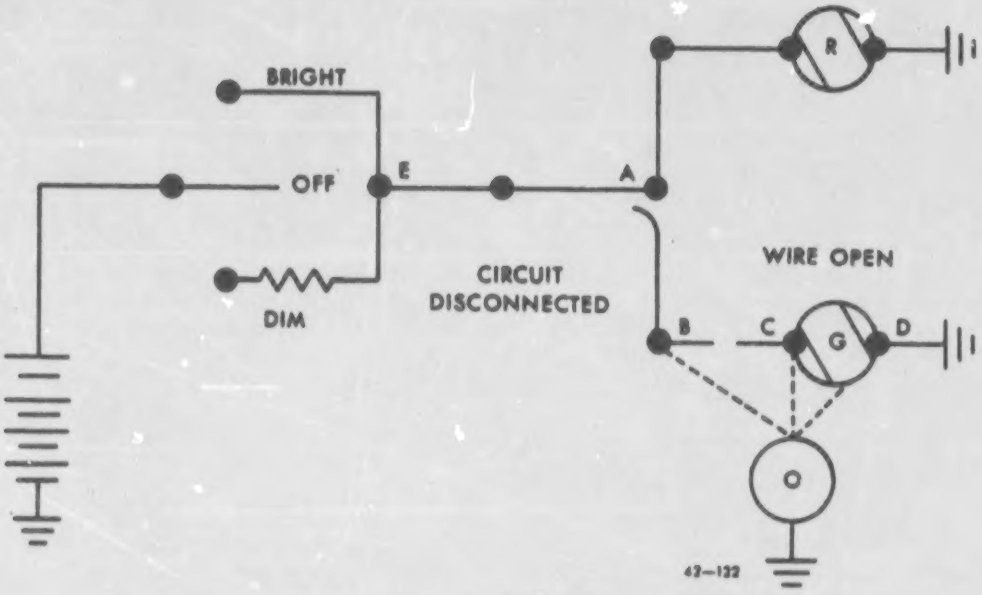

Figure 21. Troubleshooting an open circuit using an ohmmeter.

such disconnected sections is infinity. However, if a short circuit exists between the two wires, low resistance will show on the ohmmeter. An infinity reading at any of these points indicates that the two wire segments being tested are shorted to each other. Bear in mind that this method of testing for short circuits is only one of many which you may use. Probably, you may, with experience, develop your own method of using the ohmmeter in finding shorts.

6-13. Many times short circuits occur as a result of poor electrical connections in junction boxes. These boxes are metal containers which house a number of insulating strips. Each of these insulating strips has a number of stud-type posts. Wire end terminals are attached to them to join other wires for completion of the circuit. After two or more wire ends have been placed on a stud, a nut is installed to hold them together. When the nut is tightened, the wires should be held to prevent their turning with the nut. Each terminal end should have insulation over the barrel of the terminal. This prevents accidental short circuits between terminals attached to adjacent studs.

6-14. Electrical malfunctions are often caused unintentionally. *Example*: A mechanic working inside a junction box accidentally drops a screw or nut down among the maze of wires. This object will often lie there unnoticed when the work is finished. Then during a flight this loose part may be thrown about and this makes electrical contact between terminal points. The time used to extract such loose parts from any piece of electrical equipment is well spent. It may save an airplane and the lives of the crew.

6-15. **Grounded Circuits.** In aircraft wiring, the negative connection from the equipment is made to the airframe. This method of wiring uses the metallic parts of the aircraft structure as a conductor. This reduces the number of wires required. Systems so wired are called grounded systems.

6-16. Sometimes an energized lead loses its insulation and contacts the metal aircraft frame. This can be a crippling and dangerous situation. Such contact is commonly called a ground. In the true sense, this is a short circuit, as discussed in the preceding paragraphs; but, because the structure of the aircraft is included, we call them grounds or shorts to ground.

6-17. When a bare lead touches the structure, a circuit is completed. It is from the negative terminal of the power source through the aircraft structure to the point of contact. From there, it is through the lead back to the source of power. Since this circuit has little or no resistance, very large currents will flow. This large current flow will overload the wiring and cause it to burn if the circuit is not quickly broken. Heavy arcing may occur at the point of contact and burn away the metal. A hot wire touching a fuel or hydraulic line can be disastrous. Therefore, fuses and circuit breakers open the circuit as soon as the current flow exceeds a maximum amount.

6-18. It is very important that all wiring be checked periodically for any signs of insulation abrasion. If this condition is found, it should be corrected immediately to prevent further damage.

6-19. If you suspect a wire of being grounded, disconnect both ends of the suspected wire. Connect one lead of the ohmmeter to the airframe and the other lead to one end of the wire. If the wire is not grounded, it will have a resistance of many ohms (possibly millions) between it and the airframe. A circuit that is grounded will indicate no ohms resistance when the ohmmeter is connected as above. In many cases, the defective wire can be identified by its burnt appearance. A check of other wires in the group or bundle must be made to see if others have been damaged. All damaged wires should be replaced at this time to reduce the possibility of future troubles.

6-20. **Other Electrical Troubles.** The preceding paragraphs have dealt with three of the most common troubles found in aircraft circuits. You will probably find other troubles which you will have to eliminate. Keep your troubleshooting techniques flexible so that they will be adaptable to any problem.

6-21. Low or high voltage can also give you trouble. A good example would be the electric-motor-driven pump. Low voltage will cause the motor to run too slowly and overheat. High voltage will cause the motor to run too fast.

6-22. Another source of trouble is the problem of loose connections. In checking a circuit, the mechanic frequently finds it necessary to disconnect terminals at various points. He should take extreme care to reconnect the wires in the proper order and make sure that the connection is secure. If he forgets the order, he should check the TO wiring diagram before making any connections. Loose connections can cause a piece of equipment to function only part time. In addition, every time the terminals separate, an arc is produced which will, in time, burn the terminal. Replacement is not difficult, but it is costly in man-hours and aircraft operating time. Furthermore, loose electrical connections may lead to the development of short circuits.

6-23. In previous paragraphs, we mentioned the use of voltmeters and ohmmeters in checking circuits. Next, we will learn how to use test meters.

7. Use of the Volt-Ohm-Milliameter (VOM) in Locating Electrical Troubles

[illegible] Without electrical troubles, there would be a marked reduction in the work that the pneudraulic mechanic has to do. However, identifying and locating electrical troubles can be an exciting and thought-provoking part of your work. In order to do this, you will need to use a VOM (volt-ohm-milliameter). Let's briefly review a few points about this piece of test equipment.

7-2. An AN/PSM–6 series VOM, one of which is shown in figure 23, is a typical general-purpose, precision test instrument. It is used for measuring volts, amperes, and ohms. The test readings are indicated on one of three scales. They are the ac voltage scale (bottom), the dc voltage and milliampere scale (middle), and the ohms scale (top). The VOM shown in

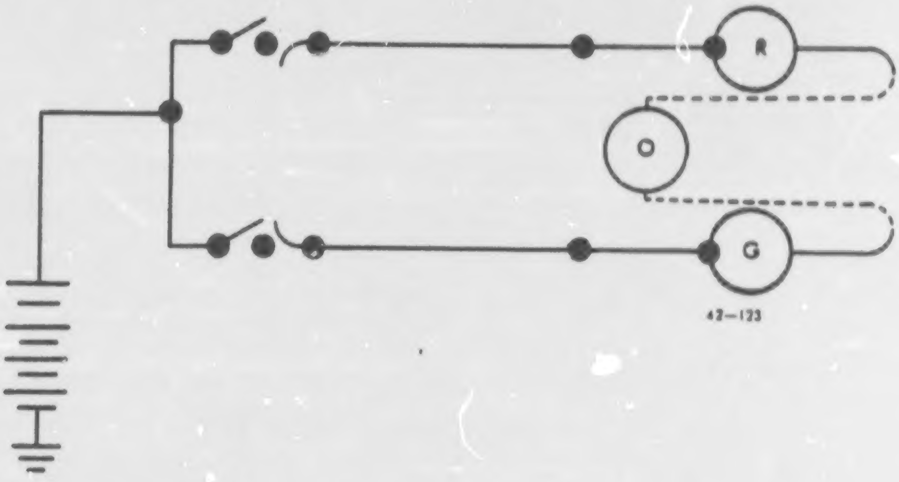

Figure 22. Troubleshooting a shorted circuit using an ohmmeter.

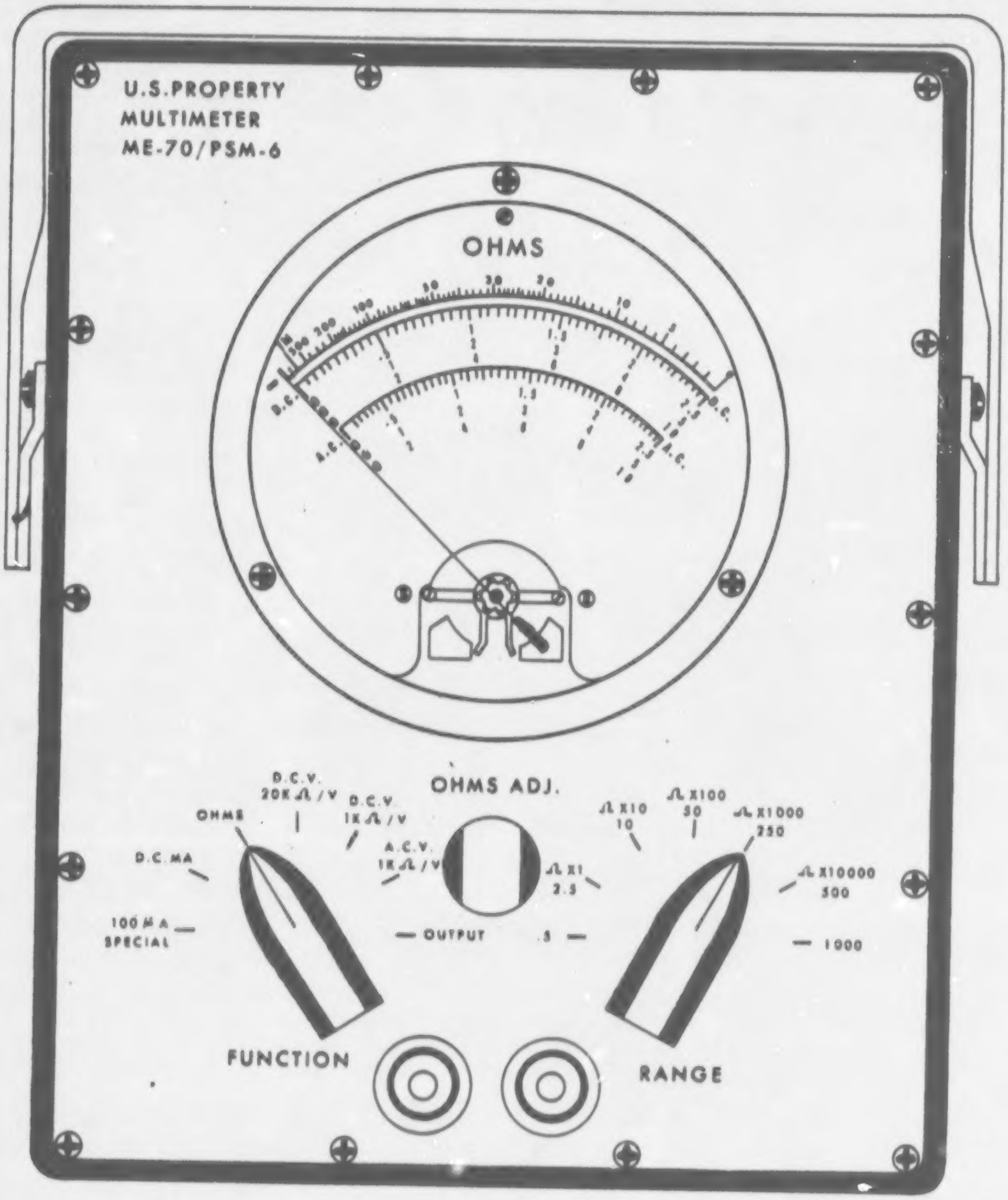
U.S.PROPERTY
MULTIMETER
ME-70/PSM-6
OHMS
D.C.
A.C.
OHMS ADJ.
D.C.V. 20K Ω/V
D.C.V. 1K Ω/V
A.C.V. 1K Ω/V
OHMS
D.C.MA
100MA SPECIAL
— OUTPUT
Ω X10 10
Ω X100 50
Ω X1000 250
Ω X1 2.5
Ω X10000 500
.5 —
— 1000
FUNCTION
RANGE
42—117

Figure 23. Typical multimeter.

figure 23' is controlled and adjusted by a RANGE selector switch for selecting the desired scale range; the FUNCTION switch for selecting the proper circuit for measuring volts, ohms, or milliamperes; and an OHMS ADJ knob for zeroing the pointer on the ohms scale. This pointer must be zeroed to compensate for a decrease in battery voltage due to age and use. The two test jacks are the plug-ins for the red (positive) and black (negative) test leads.

7-3. **Setting Up a Multimeter for Voltage Checks.** Referring to figure 23, you will notice that the FUNCTION switch has two D.C.V. (direct current volts) positions. In either position, the pointer refers to the same scale as set by the RANGE switch. The difference between the two positions is the number of ohms per volt; that is, one position (1 K /V) connects to a 1000 ohm-per-volt meter circuit; the other position (20 K /V) connects to a 20,000 ohm-per-volt meter circuit. The 1000-ohm-per-volt meter circuit protects the meter against overloads but reduces its sensitivity or accuracy.

7-4. Electrically controlled hydraulic components may be powered by either ac or dc voltage. Always check to see what type of voltage is used to operate the component. Let's assume that the components being checked operate on 28-volt dc. In this case, set the FUNCTION switch to the D.C.V. 20 K /V position. Next, set the RANGE switch to the 50-volt selection. Be sure that your setting is higher than the operating voltage of the component or circuit being tested. Next, install the test leads into the input jacks. The black lead should be placed in the black input jack and used as a ground. The red lead should be placed in the red input jack and used as the power lead. A voltmeter is always connected to the circuit in parallel and across the conductor or unit being checked.

7-5. After properly connecting the test leads, you are ready to take the voltage readings. If you have a source of 24 volts, set the RANGE switch to a 50-volt selection. The voltage reading is taken on the 0–5 division (center) of the dc scale. This scale is used for the .5–, 50–, and 500-volt selections. For example, put the RANGE selector on the 50-volt setting. If the pointer points to the 3 on the 0–5 scale, the voltage indication is 30 volts. Likewise, on the 500-volt setting, if the pointer points to the 3, the voltage indication is 300 volts.

7-6. This completes the review on setting up the VOM for voltage measurements. Let's now discuss various indications you will get when using a voltmeter in an electrical circuit.

7-7. **Voltage Indications.** From the previous discussion, you learned that a certain amount of voltage is expended in forcing current through a resistance. Any time there is a difference in voltage between two points, current flows. A voltmeter measures that difference in electrical pressure. If there is no difference between the voltmeter lead touchpoints, it will read zero.

7-8. Figure 24 shows a circuit containing several voltmeters with various voltage indications. To properly troubleshoot an electrical system, you must understand why the various voltage indications shown in figure 24 were obtained.

7-9. Notice that the voltmeter D indicates 24 volts, which is the voltage of the battery. Meters E and G indicate 24 volts, which is the amount of voltage drop across each of the light bulbs. Meter H indicates 18 volts, the voltage drop across the motor. This leaves 6 volts, which is indicated on meter B. Meters C and F indicate zero volts, because there is no voltage drop between the test leads. If there were a broken wire between the switch and the fixed resistor, H and B would read zero. All other meters would read the same as shown.

7-10. Notice that meter A indicates zero. This is true because there is no voltage drop across the switch. If this switch were opened, meter A would indicate a voltage drop of approximately 24 volts. With meter A removed, meters B and H would indicate zero voltage. These same indications would result for an opened circuit breaker. An open in an electrical wire will give approximately source voltage when a meter is placed across an open. You may be wondering why there is a 24-volt indication across an open. You may wonder especially when a motor and resistor are in series with an open. When there is an open in a circuit, there is no current flow. The entire circuit on one side of the open will have the same voltage as the battery terminal to which it is connected. The entire circuit on the other side of the open will have the voltage of the other battery terminal. There is a 24-volt difference between battery terminals. So there is a 24-volt difference across the open also.

7-11. Actually, the voltage indication across the open will be a fraction less than source voltage. The reason for this lies in the internal construction of the voltmeter. The internal resistance of a voltmeter is several thousand or possibly several million ohms. The value of a resistor and motor such as shown in figure 24 will be in the hundreds or lower thousands. When the meter is placed across the open, the circuit is again completed through the internal resistance of the voltmeter. This voltmeter resistance is much greater than the other resistance in the circuit. Therefore, almost the entire source voltage is dropped across the resistance of the voltmeter but a little does get through. That is why the reading is a little less than the source voltage. This same source voltage would be obtained even though a resistor were not installed in series with the motor. This source voltage reading is a very important factor when you are trying to isolate an open.

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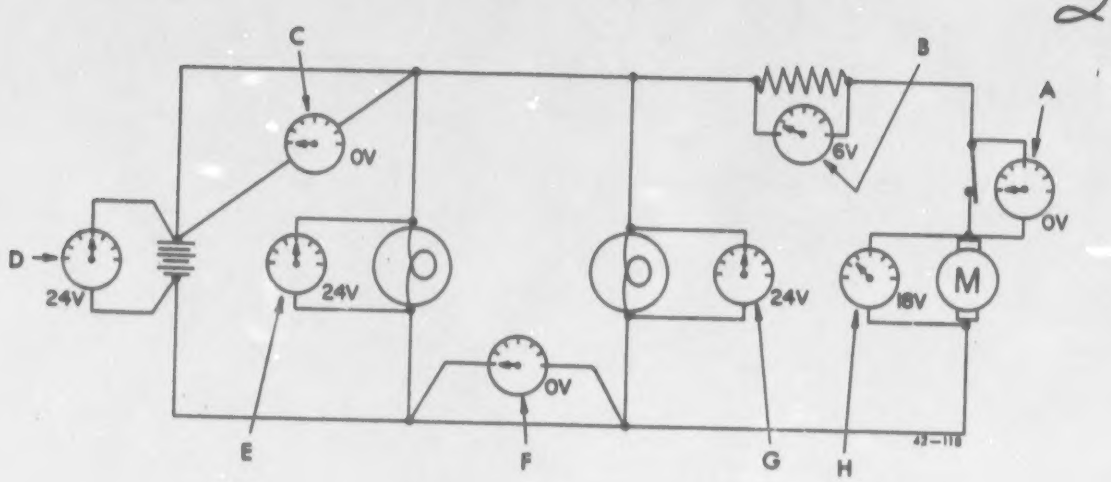


Figure 24. Voltage indications, series-parallel circuit.

7-12. **Setting Up a VOM for Ohmmeter Checks.** Refer again to figure 23. When the FUNCTION switch is set on OHMS, the meter pointer is referenced to the top scale. Resistance values are expressed in ohms. The resistance scale may seem confusing at first because it reads just backward from the other scales. However, a little time spent studying the scale will clarify this matter. When there are many ohms of resistance, only a little current will pass. This causes only a small movement of the pointer. When setting up the multimeter for ohmmeter checks, you first set the FUNCTION switch to OHMS. Set the RANGE switch to the value you estimate is enough to cover the resistance in the circuit. You may also want to consider the degree of reading accuracy required in selecting the range. (This information can be obtained from the applicable technical order.) Next, insert the test leads into the input jacks. Touch the test leads together so you can zero the meter. Gradually rotate the OHMS ADJ knob until the pointer lines up with the zero mark on the resistance scale. After zeroing the meter, you are ready to make your ohmmeter checks.

7-13. **Ohmmeter Indications.** When checking resistance with an ohmmeter, *be sure the component is disconnected from the electrical system*. Connection of the ohmmeter to a hot system could damage the meter.

7-14. *Using an ohmmeter to check components for internal opens or shorts.* When using an ohmmeter, place one test lead at the component terminal where the voltage supply wire could connect. Place the other test lead to the component's ground terminal. If more than two wires lead into the component, use the applicable schematic to determine the right wires. The meter now should give some sort of reading, depending on the amount of internal resistance of the component. A reading of infinity at this point indicates: an open caused by a broken wire, excessive corrosion, or an extremely loose connection. Conversely, a complete internal short up as a zero reading. A partial short shows up as a below-normal reading.

7-15. *Using an ohmmeter to check components for shorts between the internal circuit and the component case.* Apply one lead to the case of the component and the other lead to each of the terminals *except the ground*. In this condition, a reading of infinity indicates that the internal circuit is *not* grounded out internally. However, a reading of anything other than infinity shows that the internal circuit *is* grounded out against the case. This may be due to not enough clearance between metal parts and the case, or to broken insulation.

7-16. This completes our subject of electricity. It will not make an electrician of you and there is no reason you should be. But, you must have a basic knowledge of dc electricity and electrical circuits. Without it, you cannot hope to become an expert pneudraulic mechanic on today's aircraft.

CHAPTER 3

Pneudraulic Power Systems

EVERY AIRCRAFT hydraulic system has two major parts or sections, the power section and the actuating section (or sections). Power sections develop, limit, and direct the pressures which actuate various mechanisms on the aircraft. This chapter will deal with the different types of hydraulic and pneumatic power systems. We will discuss the different methods of developing and controlling pressure.

2. All military aircraft use hydraulic power from a small to a large degree. The use ranges from only hydraulic wheel brakes to large, complex systems with many components. On the other hand, *pneumatic* actuating systems find much less use. On a few aircraft, you will find several subsystems operated entirely by air. More common, however, are subsystems that can be operated *either* by hydraulic pressure *or* by air pressure. Also, some systems, usually brakes, are operated partly by hydraulic pressure and partly by compressed air.

8. Hydraulic Power Systems

8-1. The power section may either be an "open-center" or a "closed-center" system. It may use either an engine-driven pump or an electric-motor-driven pump. In Section 7 of Volume 2, we discussed a basic power system. It was a closed-center system in which the developed pressure is regulated by a regulator.

8-2. In this section, we will discuss specific examples of hydraulic power systems. We will see how they function and the purposes of individual units. We will also examine the types of units used in various aircraft hydraulic systems. First, we will discuss the open-center system.

8-3. **Open-Center Systems.** Flow developed by the pump in an open-center system is controlled by *open-center* selector valves. The maximum pressure developed is limited by system relief valves. In this type of system, there will be no pressure until one of the selector valves is moved from neutral. In the neutral position, the open-center selector valve directs pump output back to the reservoir. When the selector valve is moved out of neutral, pressure builds up in the power and actuating sections. This happens because the path to the reservoir is blocked. Fluid now is directed to a unit to accomplish work. Excessive pressure are prevented by the relief valve. When an open-center system is not in use, the pump is said to be idling. This occurs because there is no pressure built up in the system; therefore, there is no load on the pump. Constant-volume-type pumps are used in open-center systems.

8-4. An open-center system has fluid flow but no pressure in the system while at idle. Fluid circulates from the reservoir, through the pump, through the selector valves, and back to the reservoir. (See fig. 25, upper portion.) Selector valves in an open-center system are always connected in series. This allows free

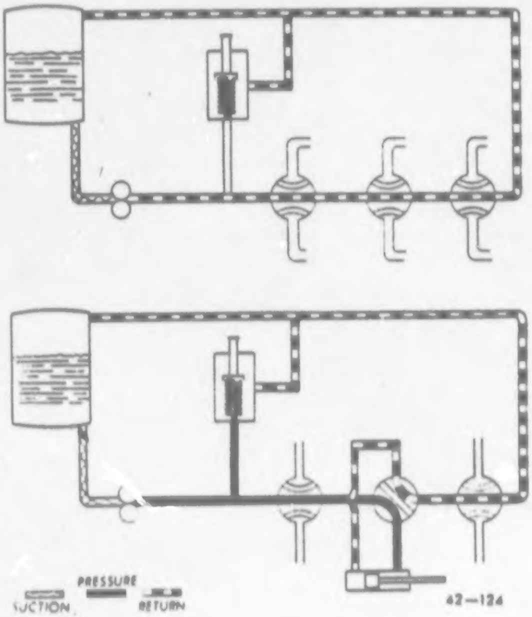
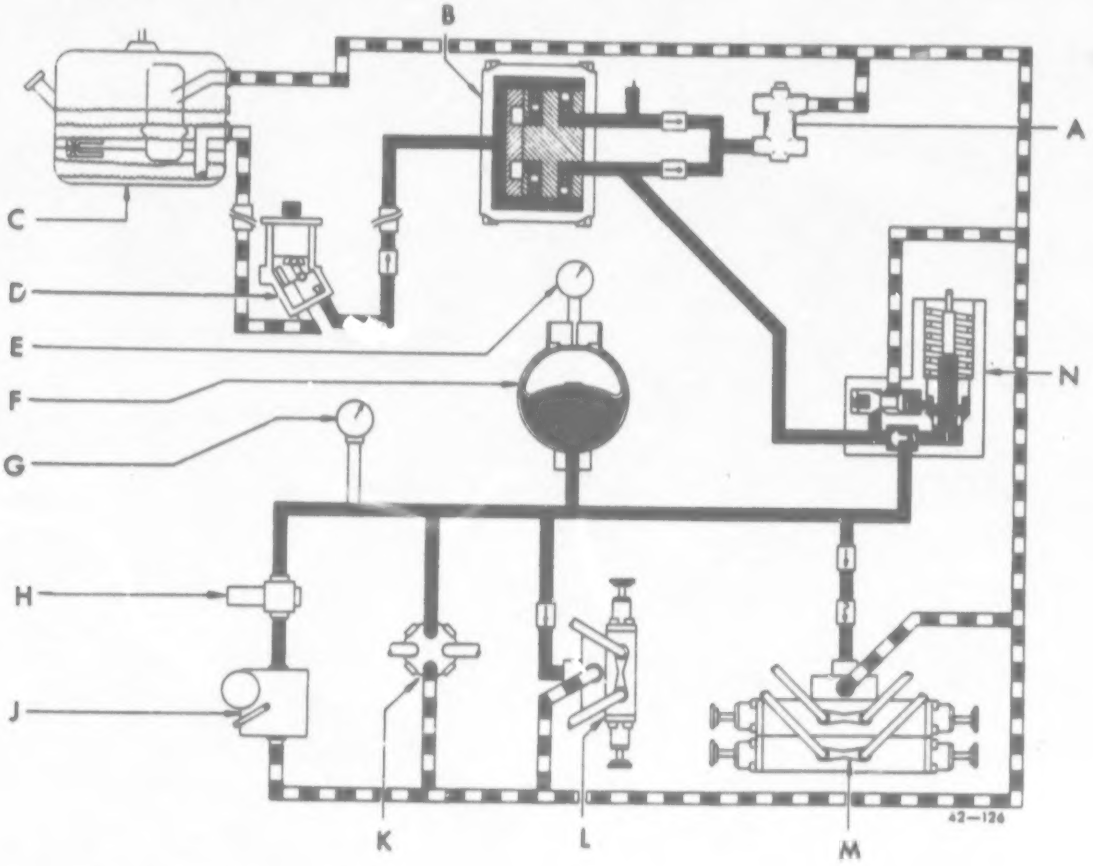


Figure 25. Basic open-center power system.

passage through each selector valve back to the reservoir. If we reposition one selector valve, the flow is diverted to that section of the system. (See fig. 25, lower portion.) Now pressure builds up in the power system and in the actuating system involved. We will not cover the open-center system in any greater detail because few aircraft use it any more. But, you will find it commonly used on hydraulic test stands.

8-5. **Closed-Center Systems.** The power pump in closed-center systems can be either constant or variable volume. The pumps are usually engine-driven but may be electric-motor-driven. The constant volume pump's flow is regulated by an external pressure regulator. In contrast, the variable volume pump has an internal control. The pressure control device directs the output of the pump (or pumps) either to the system or to the reservoir. This depends upon the pressure needs of the system at the moment. The closed-center system has fluid stored under pressure whenever the power pump is operating. However, after system pressure is built up to a predetermined value, the pump is unloaded. In this way, the pump is allowed to idle until there is a further demand made by the system.

8-6. The pump supplies the fluid needed to maintain pressure between "kick-out and kick-in" of the regulator. As long as pressure is between kick-out and kick-in, the pump is unloaded. The difference between kick-out and kick-in is called the operating range of the



A. Relief valve
B. Flow equalizer
C. Reservoir
D. Power pump
E. Accumulator air gage
F. Accumulator
G. System pressure gage
H. Nose steering shutoff valve
J. Nose steering damper unit
K. Speed brake control valve
L. Slat lock valve
M. Landing gear selector solenoid valve
N. Pressure regulator

Figure 26. Typical closed-center power system.

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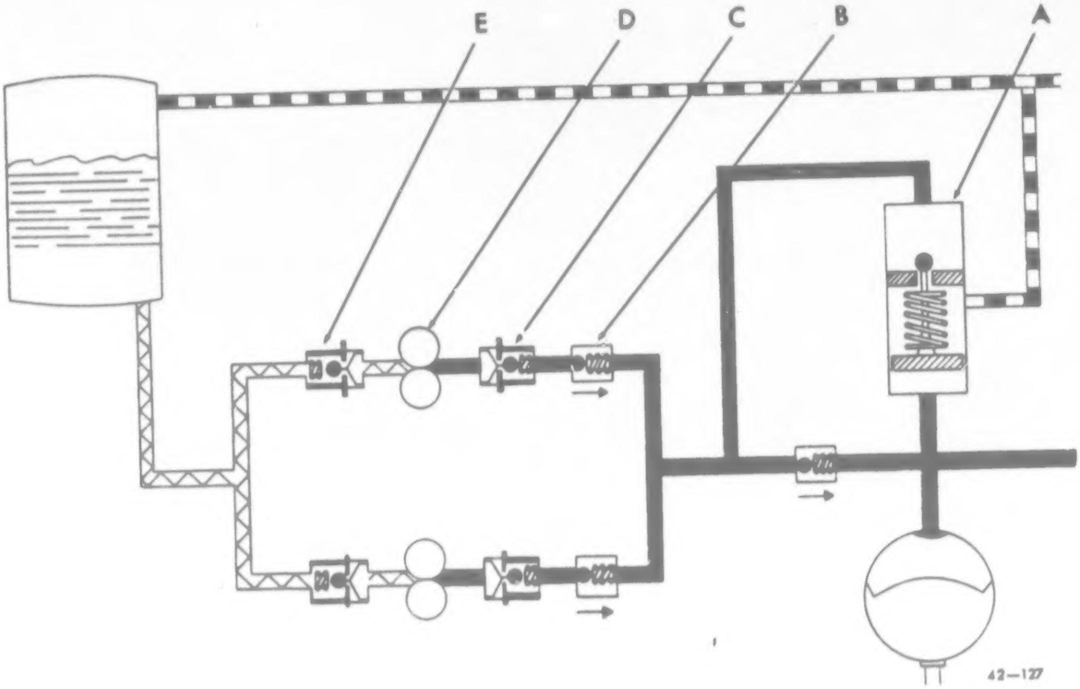
system. Do you recall the operation of a pressure regulator? Remember, when it is kicked-in, it is directing fluid to the system. As pressure reaches the desired point, the control device goes to the kicked-out position. Fluid then is bypassed back to the reservoir and the pump runs unloaded. The power section will remain in this condition until pressure is lost. This can be through leakage or operation. When the pressure drops to the kick-in point, the flow again goes to the system. This cycling will continue as long as the pump is in operation. The accumulator in the system stores pressure and smoothes out the operation of the regulator. A system relief valve safeguards the system if the regulator fails.

8-7. The selector valves of closed-center systems are arranged in parallel. With this type arrangement, more than one subsystem may operate at the same time. This is an advantage over the open-center system selector valve arrangement.

8-8. A typical closed-center system is shown in figure 26. Fluid flows from reservoir C to supply pump D. It delivers the pressure flow to the flow equalizer (B). This unit equally divides the flow between the closed-center system shown and a second system. The second system is connected to the tapoff shown downstream of the flow equalizer. The second system could be either an open- or closed-system. The flow in the system shown in the figure goes to the relief valve (A) and to the pressure regulator (N). From there, it is directed to the accumulator (F) and then to various actuating system control and selector valves. These are shown as callouts H, J, K, L and M. Return flow of fluid is passed through a filter in the reservoir to eliminate foreign matter. The system pressure gage (G) reads the system pressure. The accumulator air gage (E) gives the initial air charge pressure of the accumulator.

8-9. The hydraulic pump is the heart of the hydraulic system. However, while the human system has only one heart, the hydraulic systems have a variety of hearts or pumps. Also, a system may have more than one. We will now see how pumps are used in a closed-center system.

8-10. *Use of dual power pumps in closed-center systems.* Dual power pumps are used in many hydraulic closed-center systems. Normally, they are used on multiengine aircraft where they can be driven by separate engines.



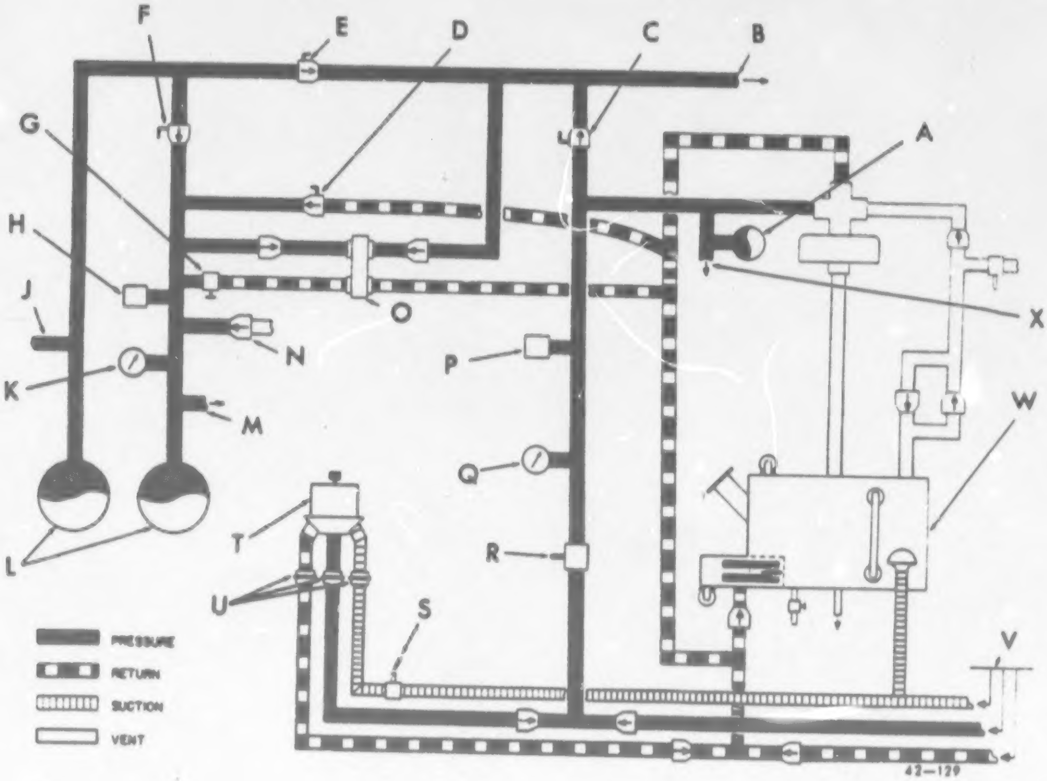
A. Pressure regulator
B. One-way check valve
C. Line disconnect
D. Power pump
E. Line disconnect

Figure 27. Closed-center system using dual power pumps.

Some of the newer aircraft have two pumps driven by the same engine. This assures hydraulic system operation should an engine fail or one of the pumps fail. Figure 27 shows how dual power pumps (D) are connected into the system. Notice that both pumps combine their volume output into a common pressure manifold. The pumps may be *either* the constant-volume or the variable-volume type. Line disconnects (C and E) are installed in the pressure and suction lines near the pump. They eliminate the need for draining the hydraulic system when the engine or power pump is changed. This arrangement also makes it easier to connect test stands. A line disconnect is a check valve which is held in the open position when connected. Upon removal of the line, the spring-loaded check valve closes, trapping the fluid in the system.

8-11. An ordinary check valve (B) is installed in the pressure line of each pump. If one pump fails, this check valve prevents motorizing the dead pump. This could otherwise damage the engine or even result in failure of the entire system. A regulator (A) is installed if the pumps are constant-volume pumps.

8-12. *Use of variable-volume pumps in closed-center systems.* Variable-volume pumps are desirable in many hydraulic systems. They differ from constant-volume pumps in that the fluid flow output varies with the pressure of the system. The higher the system pressure, the less



A. System accumulator
B. To windshield wipers
C. Controllable check valve
D. Depressurization valve (brake and nose steering systems)
E. Controllable check valve
F. Controllable check valve
G. Service shutoff valve
H. Warning light pressure switch
J. To nosewheel steering
K. Pressure gage
L. Accumulators
M. To brake control valves
N. Inlet from hand pump
O. System relief valve
P. Warning light pressure switch
Q. Pressure gage
R. Filter
S. Fire shutoff valve
T. Left-hand power pump
U. Line disconnects
V. From right-hand pump
W. Reservoir
X. To rudder boost and camera doors

Figure 28. Power system using demand-type variable volume pump.

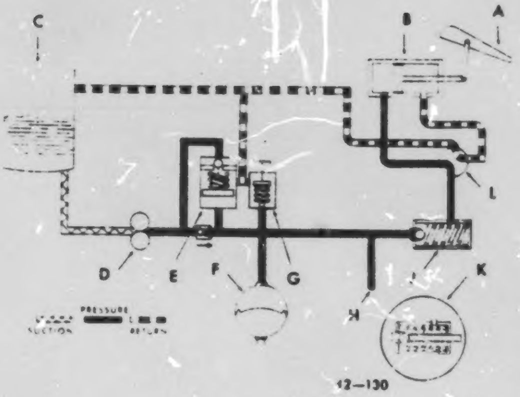
the pump output; when the system pressure reaches a predetermined setting, the pump output drops to zero. The use of this type of pump eliminates the need for a pressure regulator in the system. This results in saving weight and hydraulic tubing. There are two types of variable-volume pumps commonly used: demand-type and stroke-reduction-type.

8-13. A hydraulic system using a demand-type pump is shown in figure 28. In this type pump, the amount of fluid entering the pump is constant; the output varies with the pressure in the system. This is regulated by the pump compensator. It does this by determining the amount of fluid that is to be bypassed back to the reservoir. Output *increases* and system pressure *decreases*, and vice versa. The typical power section shown in figure 28 has two demand-type pumps (T) (only one is shown). Other components consist of a fluid reservoir (W), three accumulators (A and L), line filter (R), four (manually) controllable check valves (C, D, E, and F), a service shutoff valve (G), fire shutoff valve (S), and two low-pressure warning switches (P and H). This power section shows how various parts of the system can be isolated. This is done by the controllable check valves.

8-14. During normal operation, all controllable check valves except one (E) are closed. This permits the entire system to be charged by the engine-driven pumps. The valves act as check valves only when they are in the CLOSED position. In the OPEN position, there is free flow in both directions.

8-15. Fluid from the reservoir (W) goes to the pump (T) through the fire shutoff valve (S) and line disconnects (U). Fluid under pump pressure goes through line disconnects and check valves into a common pressure line. It continues through a line filter (R) and on to the rudder boost and camera door systems at point X. It also goes through a controllable check valve (C) to the windshield system tapoff (B) and to the system relief valve (O). Fluid also flows through the other controllable check valve (E) and again to the system relief valve (O). It can also go to the brake system tapoff (M). The nosewheel steering system tapoff (J) also receives pressure from this source. When controllable check valve F is closed, hand pump output from point N goes to the brake system only.

8-16. If valve F is open and valve C is closed, hand pump output goes to the brake system (M), nosewheel steering (J), and windshield wiper system (B). If valves F and C are both open, hand pump output is supplied to all subsystems. The pressure warning switch (P) operates a warning light if pressure in the system drops below normal. Pressure switch H turns on a warning light when brake pressure drops too low. The remaining callouts in the figure are self-explanatory.



A. Aircraft wing flap
B. Wing flap actuating cylinder
C. Reservoir
D. Power pump
E. Pressure regulator
F. Accumulator
G. System relief valve
H. To brakes
J. Priority relief valve
K. Balanced relief valve
L. Selector relief valve

Figure 29. Hydraulic power system using priority relief valves.

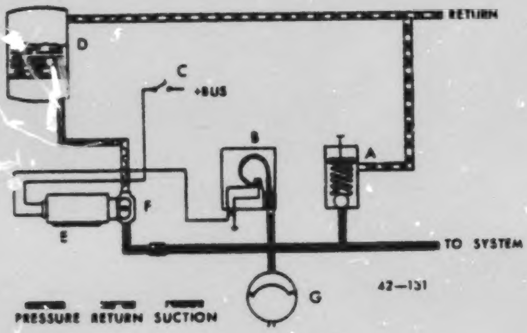
8-17. During maintenance, the controllable check valve E can be closed to prevent pressure from entering the accumulators. Controllable check valve D can be opened to depressurize the accumulators. This prevents accidental operation of the brakes and nosewheel steering. The other items connected to the reservoir are part of the reservoir pressurization system.

8-18. **Hydraulic Power Section Using Priority Relief Valve.** Today, many aircraft use a common hydraulic pressure manifold to supply fluid to the subsystems. This creates a need for a device to insure adequate brake pressure on landing if pressure drops below normal. An example is a system where brakes and wing flaps use the same pressure manifold (fig. 29). If flaps are raised soon after landing, the brakes could be inoperative because of the sudden pressure drop. This would be caused by the large amount of fluid taken from the system to operate the flaps. To prevent this situation, a priority relief valve (J) is incorporated in the system. When the system has this arrangement, pressure builds up in the primary section first. Pressure must be above the requirement for the primary system before it can go to the secondary. Thus, it is always possible to keep a minimum pressure in one part of the system—for example, in the brake system while operating the wing flaps.

8-19. A conventional relief valve is not generally used as a priority valve. This is because back pressure could affect its operation. For example, let's assume that the pressure regulator (E) kicks out at 1000 psi. The priority valve (J) is set to open at 600 psi. This is determined by the spring force. Knowing these two factors, you can figure out how much pressure is required to open this priority valve. The priority valve requires 600 psi. The pressure from the air load on the wing flap A acting on actuator B creates a back pressure equal to 500 psi. This is added to the spring force. So the pressure needed is 1100 psi.

8-20. If the pressure regulator kick-out pressure were adjusted to 1000 psi, the priority couldn't open. System pressure would then be unable to get to the wing flaps. To eliminate this problem, the pressure regulator and relief valve could be adjusted higher. However, this may not be safe, due to the maximum pressure limits of the hydraulic pumps, pressure lines, and seals.

8-21. Back pressure can be effectively eliminated without changing pressures in the system. The use of a balanced-type relief valve (K) will do the job nicely. The balanced relief eliminates the effects of back pressure by attaching a rod to the backside of the poppet (ball). This prevents back pressure from exerting its force upon the ball. This then allows the lower pressure to safely operate the wing flaps. As inlet pressure rises above the priority relief valve setting, the ball moves off its seat. At this point, there will be free flow of fluid through the valve for wing flap operation. Should the line pressure drop below the setting of the priority valve, the ball will reseat. The brake system will still retain the pressure needed for instantaneous operation. The other callouts are self-explanatory.



A. Relief valve
B. Pressure switch
C. Operator's switch
D. Reservoir
E. Electric motor
F. Power pump
G. Accumulator

Figure 30. Basic electrically operated power system.

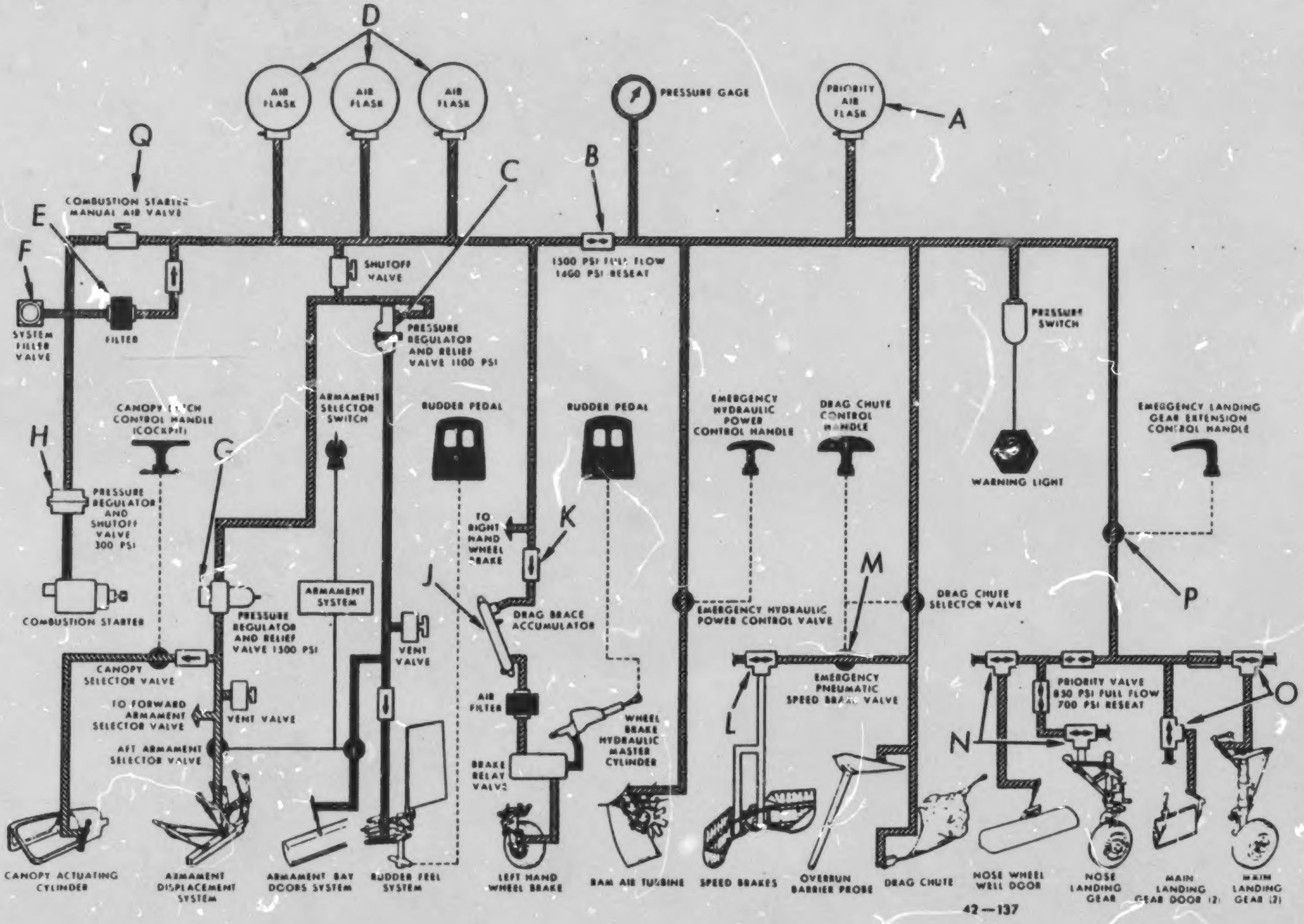
8-22. **Electrically Driven Power Sections.** These power sections are mostly used to operate auxiliary and emergency hydraulic systems. The power pump (F) may be a constant-volume type or a variable-volume type. The electric motor circuits are like the one shown schematically in figure 30. The motor (E) is started by electrical switches that are closed either manually or automatically. Electric power to the motor is turned on by a manually operated start switch (C). Pressure is maintained in the system at all times after the manual switch is closed. System pressure is held between certain set limits by the pressure switch (B). Whenever the pressure drops below its setting, the switch points close and start the motor. When pressure again rises to the desired maximum, the points open. This breaks the electric circuit, causing the pump to stop. The accumulator (G) smoothes out pressure surges and prevents rapid changes in system pressure. Relief valve A is installed to relieve excess pressures if the pressure switch fails. We might say that the pressure switch itself is a type of pressure regulator.

8-23. We have seen that we can fairly easily determine what makes up the power section of a hydraulic system. This is not the case, though, in a pneumatic system. We will attempt to find the reason for this and answer other questions concerning pneumatically operated systems in the next section.

9. High-Pressure Pneumatic System

9-1. One of the main differences between a pneumatic and a hydraulic system is the simplicity of the pneumatic power section. The pneumatic power section usually consists of one or more high-pressure air flasks, pressure gages, and pressure warning lights. Sometimes there are devices to hold back a reserve of pressure for certain essential functions. Another difference is that the pneumatic power source does not replenish itself during flight. The compressed air supply is good for only a certain number of operations. That is why many pneumatic systems are only used for emergency purposes. (There have been aircraft that had small engine-driven air compressors to refill starter system air flasks during flight.)

9-2. Because of the relatively small use of pneumatic systems in military aircraft today and also because of their simplicity, we will not discuss the power and the actuating systems separately. We will cover both in this section.


D
AIR FLASK
AIR FLASK
AIR FLASK
PRESSURE GAGE
PRIORITY AIR FLASK
A
Q
COMBUSTION STARTER MANUAL AIR VALVE
E
F
SYSTEM FILLER VALVE
FILTER
SHUTOFF VALVE
C
PRESSURE REGULATOR AND RELIEF VALVE 1100 PSI
B
1500 PSI FULL FLOW 1460 PSI RESEAT
PRESSURE SWITCH
CANOPY LATCH CONTROL HANDLE (COCKPIT)
ARMAMENT SELECTOR SWITCH
RUDDER PEDAL
RUDDER PEDAL
EMERGENCY HYDRAULIC POWER CONTROL HANDLE
DRAG CHUTE CONTROL HANDLE
WARNING LIGHT
EMERGENCY LANDING GEAR EXTENSION CONTROL HANDLE
H
PRESSURE REGULATOR AND SHUTOFF VALVE 300 PSI
G
TO RIGHT HAND WHEEL BRAKE
K
J
M
P
COMBUSTION STARTER
PRESSURE REGULATOR AND RELIEF VALVE 1500 PSI
ARMAMENT SYSTEM
VENT VALVE
DRAG BRACE ACCUMULATOR
EMERGENCY HYDRAULIC POWER CONTROL VALVE
DRAG CHUTE SELECTOR VALVE
CANOPY SELECTOR VALVE
TO FORWARD ARMAMENT SELECTOR VALVE
VENT VALVE
AFT ARMAMENT SELECTOR VALVE
AIR FILTER
WHEEL BRAKE HYDRAULIC MASTER CYLINDER
BRAKE RELAY VALVE
EMERGENCY PNEUMATIC SPEED BRAKE VALVE
L
PRIORITY VALVE 850 PSI FULL FLOW 700 PSI RESEAT
O
N
CANOPY ACTUATING CYLINDER
ARMAMENT DISPLACEMENT SYSTEM
ARMAMENT BAY DOORS SYSTEM
RUDDER FEEL SYSTEM
LEFT HAND WHEEL BRAKE
RAM AIR TURBINE
SPEED BRAKES
OVERRUN BARRIER PROBE
DRAG CHUTE
NOSE WHEEL WELL DOOR
NOSE LANDING GEAR
MAIN LANDING GEAR DOOR (2)
MAIN LANDING GEAR (2)
42—137

A. Priority air flask
B. Priority valve
C. Regulator and relief valve assembly
D. Nonpriority air flasks
E. Filter
F. Ground test filler connection
G. Regulator and relief valve assembly
H. Regulator and solenoid shutoff valve assembly
J. Drag brace accumulator
K. Check valve
L. Shuttle valve
M. Selector valve
N. Shuttle valves
O. Shuttle valves
P. Selector valve
Q. Starter manual valve

Figure 31. High-pressure pneumatic system.

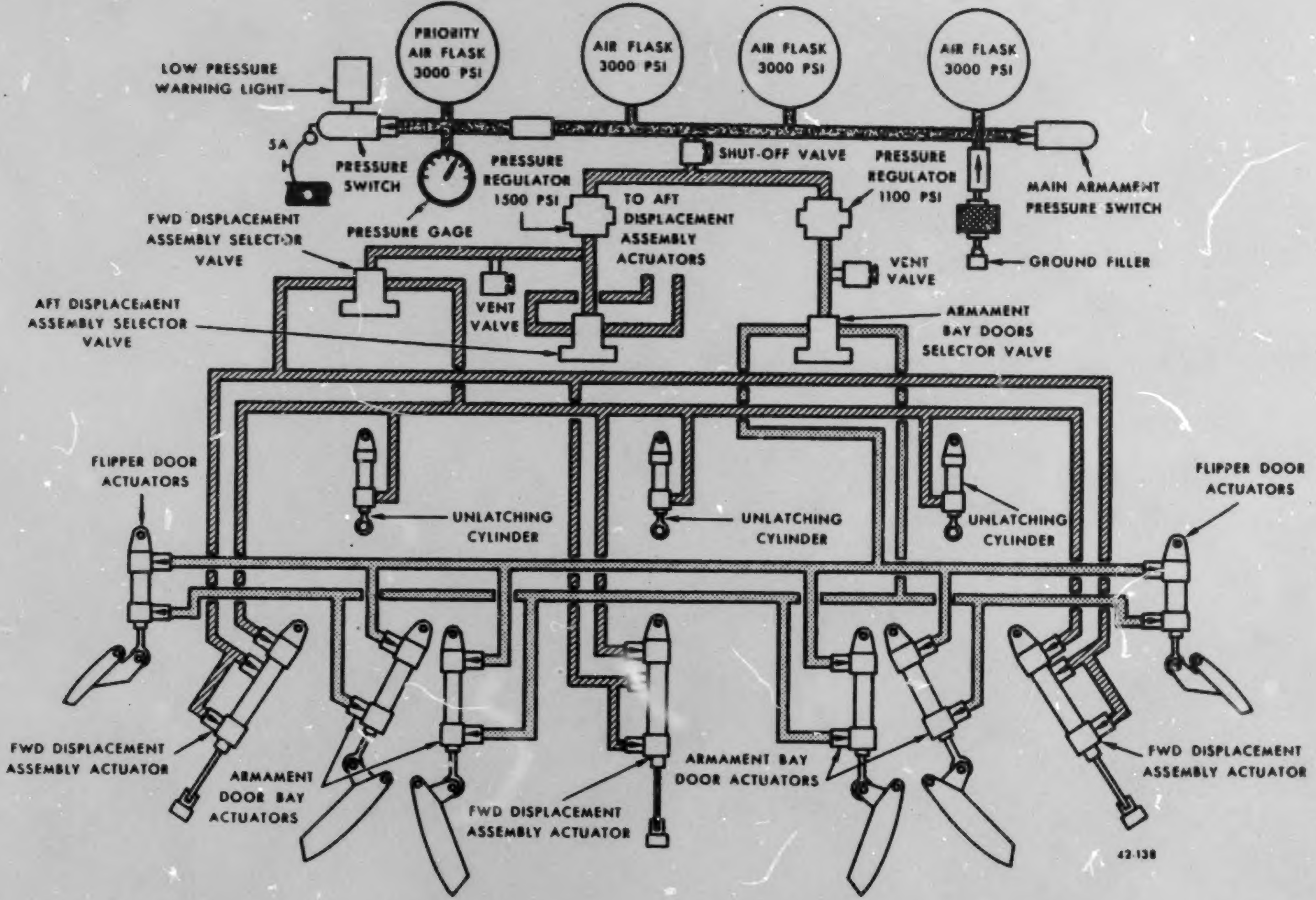

PRIORITY AIR FLASK 3000 PSI
AIR FLASK 3000 PSI
AIR FLASK 3000 PSI
AIR FLASK 3000 PSI
LOW PRESSURE WARNING LIGHT
5A
PRESSURE SWITCH
SHUT-OFF VALVE
PRESSURE REGULATOR 1500 PSI
PRESSURE REGULATOR 1100 PSI
MAIN ARMAMENT PRESSURE SWITCH
TO AFT DISPLACEMENT ASSEMBLY ACTUATORS
FWD DISPLACEMENT ASSEMBLY SELECTOR VALVE
PRESSURE GAGE
GROUND FILLER
VENT VALVE
VENT VALVE
AFT DISPLACEMENT ASSEMBLY SELECTOR VALVE
ARMAMENT BAY DOORS SELECTOR VALVE
FLIPPER DOOR ACTUATORS
FLIPPER DOOR ACTUATORS
UNLATCHING CYLINDER
UNLATCHING CYLINDER
UNLATCHING CYLINDER
FWD DISPLACEMENT ASSEMBLY ACTUATOR
ARMAMENT DOOR BAY ACTUATORS
FWD DISPLACEMENT ASSEMBLY ACTUATOR
ARMAMENT BAY DOOR ACTUATORS
FWD DISPLACEMENT ASSEMBLY ACTUATOR
42-138

Figure 32. Armament pneumatic system.

First, let's consider some general characteristics including those of the power section.

9-3. **General Pneumatic Information.** Aircraft pneumatic systems are mostly used as an emergency source of pressure for hydraulically operated subsystems. However, in some cases, air is the source of pressure to normally actuate units. Figure 31 is a schematic of a typical high-pressure pneumatic system and its component parts. High-pressure pneumatic systems are constructed to operate in much the same manner as hydraulic systems.

9-4. A shuttle valve is used to connect the pneumatic system to the hydraulic system. This allows the use of the same tubing and units for both systems. Notice in figure 31 that the speed brake, nosewheel well door, nose landing gear, main landing gear, and landing gear doors have shuttle valves (L, N, and O). They separate the normal hydraulic system from the pneumatic system. Pneumatic system selector valves (M and P) control the air to these subsystems. The remaining subsystems in figure 31 have components which are normally actuated by air pressure. Each subsystem is connected to the high-pressure pneumatic air source through a pressure regulator and relief valve assembly (C, G, and H) and a selector valve. Pneumatic selector valves are installed in parallel. Therefore, air pressure is immediately available to all subsystems for instant operation. Connected in this manner, more than one system can be operated at the same time. In a pneumatic system, the return lines from the selector valves are vented to the atmosphere. This is also true of the pressure regulator and relief valve.

9-5. Referring to figure 31, notice that air for the high-pressure pneumatic system is stored in four flasks. Three are nonpriority air flasks (D) and one is a priority air flask (A). Air is also stored in the two drag brace accumulators (J) (only one is shown). The flasks and accumulators are charged simultaneously through a ground test filler connection (F). A portable nitrogen cart or high-pressure air compressor is used to service the flasks. All nitrogen or air is filtered by filter E in the service line. The following subsystems are operated from the storage flasks: combustion starter, canopy, armament displacement actuators and bay doors, drag chute and barrier overrun probe, rudder feel, wheel brakes, and ram air turbine. Pressure is available for emergency operation of the landing gear and speed brake systems if the hydraulic system fails. Notice that a priority valve (B) is installed between the priority flask (A) and nonpriority flask (D). If pressure is above 1400 psi, air can flow both ways through the valve. The priority valve saves the last 1400 psi of air pressure to operate the ram air turbine, drag chute, speed brakes, and landing gears. A pressure switch and warning light are installed to warn the pilot if pressure drops to 1500 psi.

9-6. **Starter System.** Refer to the left side of figure 31. The starter system consists of a manual shutoff valve, solenoid-operated pressure regulator shutoff valve, and starter. The pneumatic starter for the aircraft engine uses high-pressure air from the air flasks or an external unit. The manual shutoff valve (Q) permits the starter to be run from a ground air compressor. It isolates the starter from the aircraft storage flasks. It must be opened though when the aircraft pneumatic supply is to be used. A combination regulator and shutoff valve reduces the air pressure to 300 psi for starter operation. After startup, the manually operated shutoff valve will always be put into the OFF position (ground supply).

9-7. **Armament System.** The schematic in figure 32 represents one half of the armament system. The system consists of pressure regulators, selector valves, cylinders, restrictors, and check valves. The armament bay doors are operated by 1100 psi and the displacement actuators by 1500 psi. The doors are locked in the up position by internal locks *in the actuators.* The internal locks are unlocked when opening pressure is applied to the actuating cylinders. As you study the schematic, notice that one air line to the displacement actuators applies air pressure to two different areas. This line is the up line. One area is to the normal retraction side, and the other is to the buffer chamber. The purpose of this buffer chamber is to trap 1500 psi of air. It slows the retract cycle of the cylinder and prevents damage to the assembly. This process of slowing the operation is called snubbing. Restrictors in the open and close ports of cylinders allow free inflow of air but restrict the outflow. This restriction provides further snubbing action in the cylinders. Snubbing also controls the length of time for door opening and closing.

9-8. **Wheel Brake System.** Air brakes operated by hydraulic relays are installed on the main landing gear. Air pressure for brake operation is stored in the hollow main landing gear drag braces. The drag braces serve as an accumulator, storing air at 3000 psi. Drag brace accumulators are shown in figure 33. They always hold enough pressure for braking even if all other air pressure is lost. The aircraft brake system consists of: two master brake cylinders, relay valves, drag brace accumulators, relief valves, check valves, and air filters. The brake system is hydraulically controlled and pneumatically operated.

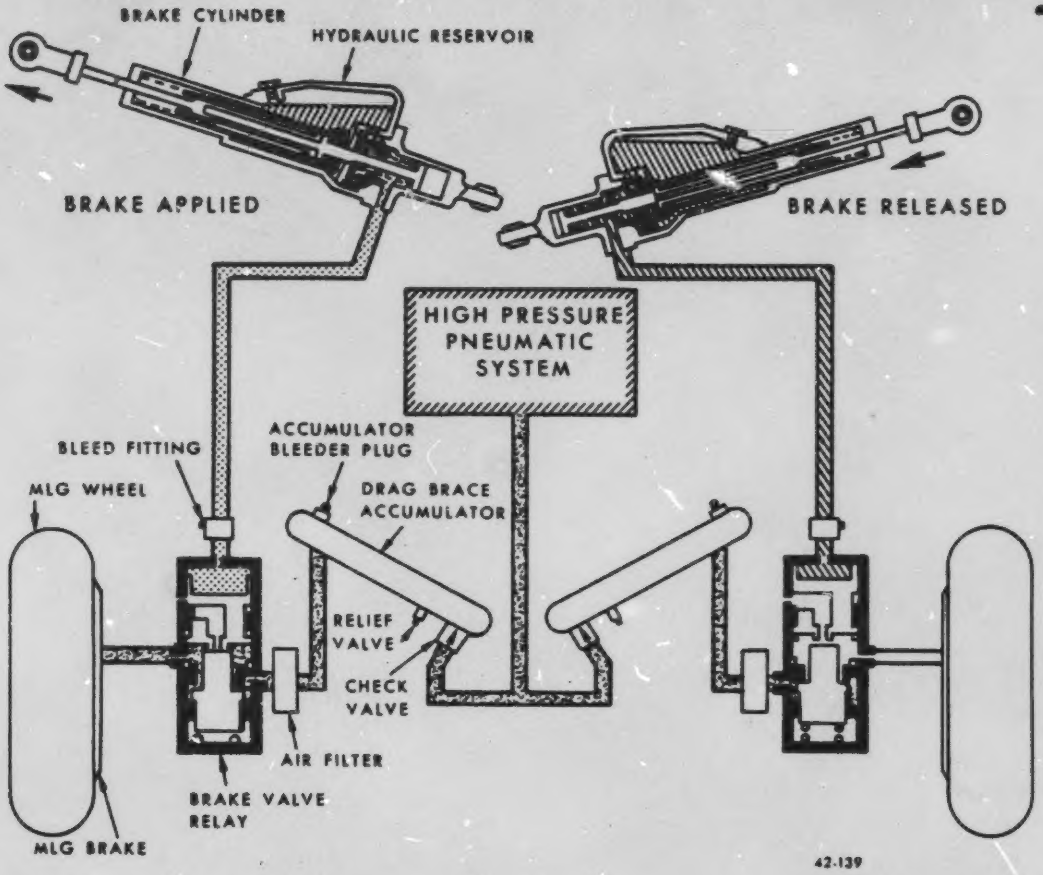

BRAKE CYLINDER
HYDRAULIC RESERVOIR
BRAKE APPLIED
BRAKE RELEASED
HIGH PRESSURE PNEUMATIC SYSTEM
BLEED FITTING
ACCUMULATOR BLEEDER PLUG
MLG WHEEL
DRAG BRACE ACCUMULATOR
RELIEF VALVE
CHECK VALVE
AIR FILTER
BRAKE VALVE RELAY
MLG BRAKE
42-139

Figure 33. Pneumatic brake system.

9-9. The airbrake system that is shown in figure 33 is operated by using the rudder pedals. The pedals are mechanically connected to the brake master cylinders. The pedal movement causes fluid to flow from the master cylinder and creates pressure. This pressure operates the brake relay valves. The brake relay valves then direct air pressure from the drag brace accumulators to the brake assembly. Check valves installed upstream in the pressure line isolate the drag brace from the main air system. Air filters are installed for the purpose of cleaning the air before it reaches the brake relay valves.

9-10. Air pressure regulators and relief valve assemblies are installed in each subsystem. The relief valves are incorporated within the regulator assemblies. Together, they reduce the air pressure to the desired value. The relief valve prevents overpressurization of these systems in the event of a regulator malfunction. Three main system relief valves have been installed in the main system to limit maximum system pressure. There is one relief valve for each drag brace and one downstream of the priority flask (not shown).

9-11. This concludes our discussion of hydraulic power sections and pneumatic power and actuating systems. The next chapter will discuss hydraulic actuating systems.

CHAPTER 4

Hydraulic Actuating Systems

THE PURPOSE of any hydraulic system is to provide a means of doing useful work. Can you imagine cranking a landing gear or wing flaps up or down by hand? Not many years have elapsed since some military aircraft used this manual method. Modern aircraft are more powerful and much larger, and their components are heavier. Today's aircraft fly much faster, and therefore their control surfaces are subjected to greater loads. It would be hard for a pilot to operate the flight controls without power assist in today's high performance aircraft. Furthermore, it would not be very practical. Although our present-day aircraft systems are hydraulically actuated, some of them incorporate manual emergency operation.

2. We have discussed the enormous mechanical advantage that may be obtained with the use of a hydraulics. In Chapter 3, we discussed the power section. You were shown how we obtained and controlled a stable hydraulic fluid pressure supply.

3. In this chapter, we will discuss the actuating sections which use the pressure supply to move various aircraft units. Some actuating sections are more complex than others. Complicated followup mechanisms or intricate electrical systems are incorporated in some. The detailed description and operation of these systems is beyond the scope of this course. However, a general knowledge of systems is essential to the pneudraulic mechanic. With this knowledge, he can perform both the necessary inspections and maintenance.

4. Actuating systems can be divided into categories on the basis of various factors. Several bases for division will be used in this chapter to best accomplish our purpose. We will first consider actuating systems and their units as belonging to two classes—nonautomatic and automatic. These will be presented in Sections 10 and 11. In each section, we will use specific actuating systems as examples and to show variations.

5. In Section 12, a group of systems will be given which we will classify as miscellaneous. The function and size of these systems vary from those to be covered in Sections 10 and 11. Also, they combine some nonautomatic and automatic features.

6. Finally, in Section 13, we will study actuating systems that seem to differ enough from all others to be placed by themselves. These, too, seem to combine a variety of features. So, now, let's get on with the nonautomatic type of systems.

10. Nonautomatic Actuating Systems

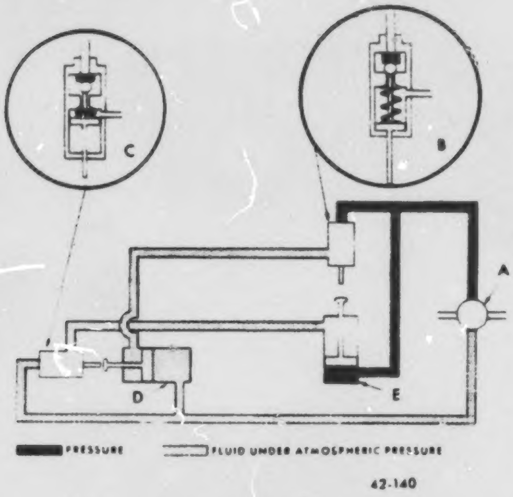
10-1. Nonautomatic actuating systems are used when full travel of the actuator is required for each operation of the unit. Landing gear and bomb-bay door systems are examples of this. We will examine specific examples of various nonautomatic actuating systems, their principles of operation, design features, and function in the hydraulic system.

10-2. Nonautomatic actuating systems are manually controlled by the operator. When the selector valve is moved to an operating position, fluid pressure (main pressure line) is sent to the actuating cylinder. The piston moves to its extreme limit of travel. To stop the piston before the end of its travel, he must return the selector valve to neutral. Most valves have a neutral position. The simplest nonautomatic control section contains a selector valve and an actuating cylinder.

10-3. In some systems, one operation must be performed before the rest of the system can operate. Therefore, the operation of the various system units must occur in proper sequence. Control of a sequenced system is applied by mechanical, electrical, or hydraulic means. Devices such as microswitches, relief valves, and hydraulic sequence valves are used in sequenced systems.

10-4. **Mechanically Sequenced System.** A mechanically sequenced system uses the linkage of a unit to position the sequence valves. A typical system of this type is shown in figure 34.

10-5. As an example, let us consider a simple



A. Selector valve
B. Sequence valve closed (landing gear)
C. Sequence valve open (door)
D. Actuating cylinder (door)
E. Actuating cylinder (landing gear)

Figure 34. Mechanically sequenced system.

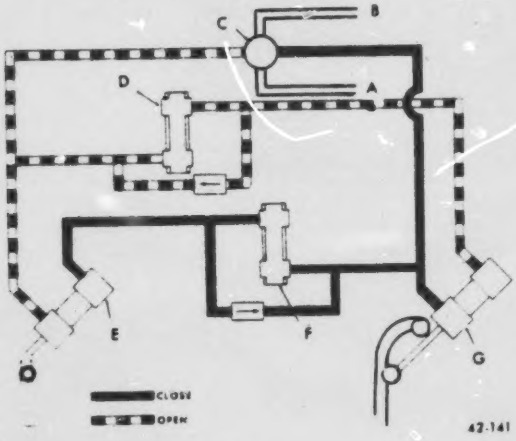
landing gear system incorporating wheel well doors it is clear that the doors must not close before the gear is retracted. Also, the doors must open before the landing gear is extended. Let us suppose that the pilot has positioned the selector valve (A) to retract the landing gear. Pressure is then directed to the up side of the landing gear actuating cylinder (E). At the same time, pressure goes to the landing gear sequence valve (B). At this time, sequence valve B is closed. Therefore, pressure can flow only to the up side of the landing gear actuating cylinder. Sequence valve C is in the open position to allow the return flow from the actuator to the reservoir. As the retraction nears completion, the actuating cylinder starts to position sequence valve B. This occurs when the piston rod in E extends far enough to contact the piston rod of sequence valve B. As the piston of the sequence valve moves, it pushes the ball off its seat and opens the valve. Fluid under pressure is now allowed to flow to the door actuating cylinder (D).

10-6. As the doors close, the actuator linkage draws away from the rod in sequence valve C. It releases the spring loaded piston rod of the sequence valve (C) which closes the valve. During gear extension, the selector valve (A) first directs pressure to the door actuating cylinders. When the doors are open, mechanical contact is made with the door sequence valve (C) and opens it. This allows the fluid pressure to continue on to the landing gear actuating cylinder (E) to extend the gear. Return fluid from the door actuating cylinder (D) is routed through the landing gear sequence valve (B), which is still open.

10-7. **Pressure Sequenced System.** Pressure sequencing is used on some types of aircraft. A bomber using spoilers together with the bomb-bay doors is an example. The spoilers are opened first to protect the bomb doors from the airstream. This type of sequencing is done with a relief valve. It is set to open at a higher pressure than needed to operate the first actuating mechanism. The spoiler will open before pressure is high enough to open the doors. With the spoiler open, pressure will build up and open the relief valve. The flow then can go to the door actuators.

10-8. An example is shown in figure 35. With selector valve C in the OPEN bomb door position, pressure is sent to the open side of the spoiler actuator (E). It is also sent to the relief valve (D). The pressure needed to operate the spoilers is less than that required to open the relief valve. Therefore, only after the spoilers are open and no more piston travel is possible, can the pressure increase. Now it can increase to the setting of the relief valve. When the relief valve opens, pressure is applied to the bomb door actuator to open the doors.

10-9. When the selector valve is turned to CLOSE, pressure (now represented by the solid line) is directed to the close side of actuator G. At the same time, pressure also goes to relief valve F. The pressure required to close the



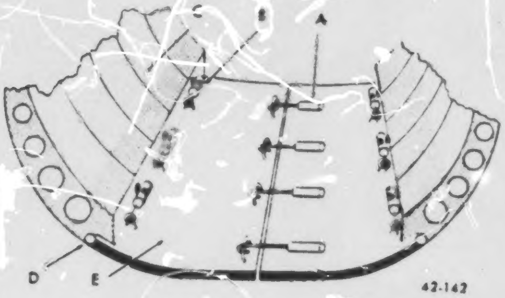
A. Return line
B. Pressure line
C. Selector valve
D. Relief valve
E. Spoiler actuating cylinder
F. Relief valve
G. Bomb door actuating cylinder

Figure 35. Pressure sequenced system.

doors is less than the pressure settings of the relief valve. When the doors are closed, the pressure continues to increase until it opens the relief valve. Opening of the relief valve allows the pressure to continue to the close side of the spoiler actuator (E). A check valve is used in conjunction with each relief valve so that returning fluid from the actuator bypasses the relief valve. It then continues, unrestricted, through the selector valve to the reservoir.

10-10. **Electrically Sequenced System.** In a hydraulic system with electrically sequenced valves, the control is a solenoid or motor. The electricity to the valves is controlled by microswitches. The microswitches are actuated by hydraulic units of the system they are in. Electrically operated sequence valves can be used to operate a system like the one in figure 36. The size and shape of the doors will determine the number of latches (A and B) used to hold the doors (E) closed. These latches must operate in proper sequence to prevent damage to the doors (E) and fuselage (C).

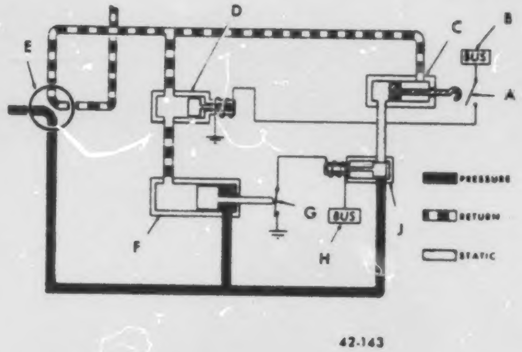
10-11. During door opening, the jamb latches (B) must open before the center latches (A). The jamb latches are near the hinge line (D). Should the center latches open first, the doors' weight would cause the doors to open part way. This would put a severe strain on the jamb latches. After the doors close, the center latches pull them tightly into place and lock them. The center latches must close first, insuring that the doors are in place. Then the jamb latches slide into their locking position.



A. Center latches
B. Jamb latches
C. Fuselage structure
D. Hinge point of door
E. Doors

Figure 36. Cargo loading doors latch arrangement.

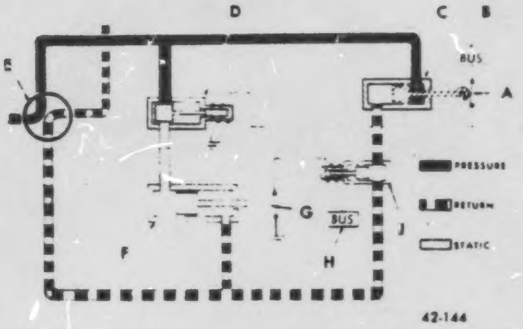
10-12. Figure 37 is a schematic of the unlatching process for figure 36. To simplify the explanation, one jamb latch is shown to represent all six. One center latch is shown to represent the four in figure 36. In figure 37 the solenoid in sequence valve D will close when electrical power is applied. Placing the latch selector valve (E) to the unlatch position directs pressure to the jamb latch actuators (F) and to the sequence valve (J). At the start, the sequence valve (J) is energized in the closed position. Note the position of sequence switch G. This prevents hydraulic pressure from going to the center latch actuator (C). As jamb latch actuator F moves to the unlatch position, switch G opens and deenergizes sequence valve J. This opens sequence valve J and allows pressure to go to the unlatch side of center latch C. (The sequence valve switch G cannot be opened until the last jamb latch is completely open.) As the last center latch opens, its piston rod closes sequence valve switch A. This energizes and closes sequence valve D. This completes the unlatching of the doors. Other hydraulic valves and actuators are used to open the doors and lower the ramps.



A. Sequence valve switch
B. Source of electrical power
C. Center latch actuator
D. Sequence valve
E. Selector valve
F. Jamb latch actuator
G. Sequence valve switch
H. Source of electrical power
J. Sequence valve

Figure 37. Electrical sequence system (doors unlatching).

10-13. Now let's study the latching sequences. Let us assume that the doors have been closed and are ready to be latched. Remember that the doors must be tightly closed and latched before the jamb latches can be properly operated. To latch the doors, move the selector valve (E) to the position as shown in figure 38. Hydraulic pressure is then sent to the latch side of the center latch actuator (C) and the sequence valve (D). The sequence valve (D) is energized to the closed position, and prevents hydraulic pressure from going to the jamb latch actuator (F). As the last center latch C moves to the latched position, switch A opens, deenergizing opening sequence valve D. There are actually four switches (one of which is labeled A in figure 37) hooked in series. This



A. Sequence valve switch
B. Source of electrical power
C. Center latch actuator
D. Sequence valve
E. Selector valve
F. Jamb latch actuator
G. Sequence valve switch
H. Source of electrical power
J. Sequence valve

Figure 38 Electrical sequence system (doors latching).

allows hydraulic pressure to close the six jamb latch actuators (F). As the last jamb latch is closed, the last sequence valve switch G closes. This causes the sequence valve (J) to be energized and closed.

10-14. **Landing Gear Systems.** The landing gear used in this discussion is an electrically sequenced system. You will better understand the operation of the system by tracing its fluid flow. We will cover both extension and retraction operations. Figures 39 through 43 illustrate the complete sequence.

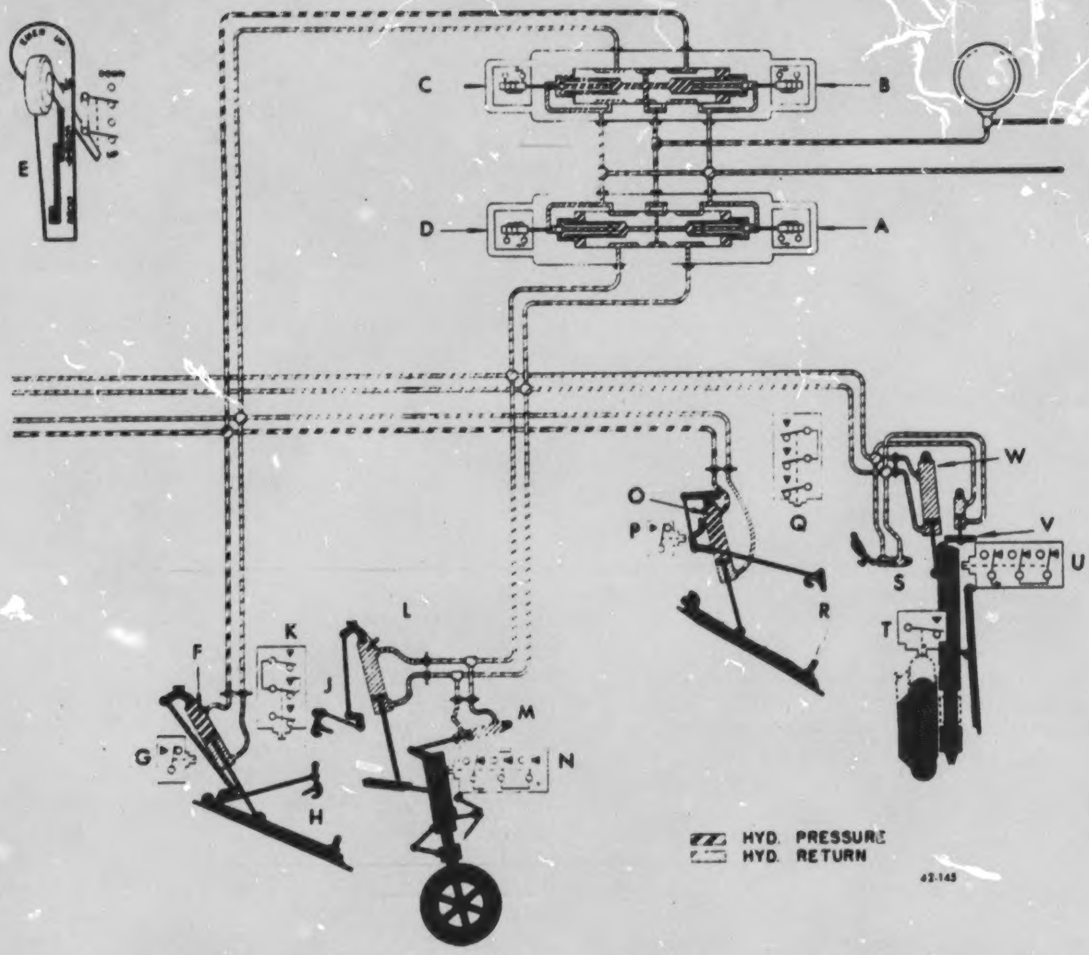
10-15. The movement of the doors is controlled by sequence switches mechanically operated by the main gear. The system consists of landing gear and door control valves, actuating cylinders, restrictors, and check valves. The control valves are operated by electric solenoids which are controlled by microswitches.

10-16. Let us suppose that the aircraft has taken off and the pilot is retracting the gear. Use figure 39 to follow the sequence of events that takes place. The two lines in the upper right of the figure are the hydraulic pressure and return source manifolds. Hydraulic pressure is applied to the solenoid valves any time there is pressure in the manifold. Both the door and gear control valves are returned to the neutral position by hydraulic pressure. They are moved out of neutral by electric solenoid action. By placing control handle E to the UP position, the door open solenoid (C) is energized. The rod and ball of the solenoid are pulled to the left. This action causes the ball to unseat from the sliding spool of the control valve. As the ball moves off its seat, a path for fluid flow to return is formed. Fluid can now leave the left end of the control valve and go back to the reservoir. When this happens, the pressure at the right end of the spool forces the spool to the left. Pressure can now get out of the pressure port as shown in figure 40. The fluid flows to the open side of door, actuating cylinders F and O. The initial movement of cylinders F and O pulls the door locks (H and R). This releases the doors. When the doors reach the full down position, they contact gear up sequence switches G and P.

10-17. As the doors close sequence switches G and P, electrical power is applied to the gear retract solenoid (D). The same action takes place to cause the spool to move left as in the door valve. Pressure is directed to gear-actuating cylinder L, helper cylinder M, gear up-lock cylinder S, gear-actuating cylinder W, and gear down-lock cylinder V. (See fig. 40.) Gear down-lock V will actuate before gear actuating cylinder W ever moves because it requires much less pressure. After the down locks are pulled, hydraulic pressure continues to the up side of the main gear cylinders (W). When each gear reaches the *up* and *locked* position, figure 41, it contacts microswitches K and Q. After the microswitches have made contact, the electrical circuit is cut off from the doors open solenoid (C). Now electrical power is directed to the doors closed solenoid (B). This shifts the spool position to the right. Hydraulic pressure now flows to the doors closed side of the door actuating cylinders (F and O). As the *doors* move from the full open position, the electrical circuit deenergizes gear up solenoid D. The gear control valve spool shifts back to neutral. With the gear control valve in this position, both gear ports are connected to return. When the door is up and locked, solenoid B remains energized until control handle E is moved to the COMBAT position. Then it is deenergized and the spool goes to neutral. In neutral both door lines are opened to the return manifold. This is a safety factor for combat conditions; it reduces the number of pressurized hydraulic lines. A combat position is used on some combat aircraft. Many aircraft use selector valves that go to neutral when all gears are up and the doors are closed. Each aircraft system has its own characteristics.

10-18. An additional safety factor prevents accidental gear retraction while the weight of the aircraft is on the ground. When the left main gear shock strut is compressed, a ground safety switch (T, fig. 39) breaks contact in the gear up circuit. The electrical circuit is completed when the shock strut is fully extended.

10-19. When the control lever is moved to the DOWN position (see fig. 42), the electrical circuit energizes door open solenoid C. Also,

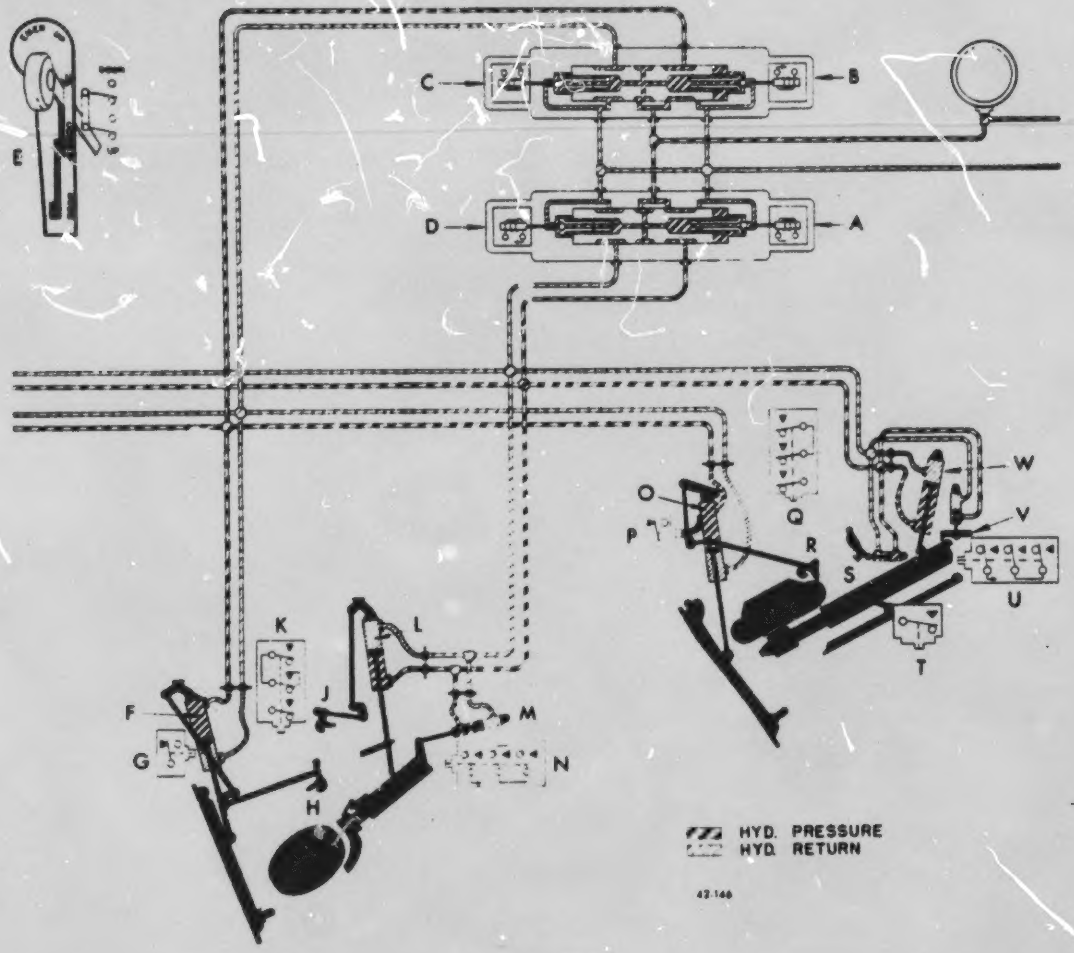


A. Extend gear solenoid
B. Door closed solenoid
C. Door open solenoid
D. Retract gear solenoid
E. Control handle
F. Door actuating cylinder
G. Gear up sequence switch
H. Door up-lock
J. Gear up-lock
K. Door sequence switch
L. Gear-actuating cylinder
M. Helper cylinder
N. Door sequence switch
O. Door actuating cylinder
P. Gear up sequence switch
Q. Door sequence switch
R. Door up-lock
S. Gear up-lock and cylinder
T. Ground safety switch
U. Door sequence switch
V. Gear down-lock and cylinder
W. Gear-actuating cylinder

Figure 39. Landing gear operation—control handle up, gear down.

extend gear solenoid A is energized. One control spool shifts to send hydraulic pressure to the open side of the door cylinders. The other spool sends pressure to gear actuating cylinder L and helper cylinder M, gear actuating cylinder W, gear down-lock V, and gear up-lock S. This action first unlocks gear up-locks S and J, and locks gear down-lock V. The gear usually falls part way by its own weight, but pressure takes it the final distance. When each gear reaches the down and locked position, it presses microswitches N and U (fig. 43). When the gear microswitches have made contact, the electrical circuit is broken to the doors open solenoid. At the same time, a circuit is completed to energize the doors closed solenoids. So, the spool in the valve shifts and sends pressure to the close side of the door actuators F and O (fig. 43). When the doors are closed and locked (H and R), a microswitch breaks the electrical circuit to solenoid B. The control spool returns to neutral, and the gear lines too are connected to the return manifold.

10-20. This concludes our discussion of nonautomatic actuating systems. Several pages back you may have said to yourself, "All this sequencing looks pretty automatic to me." But,



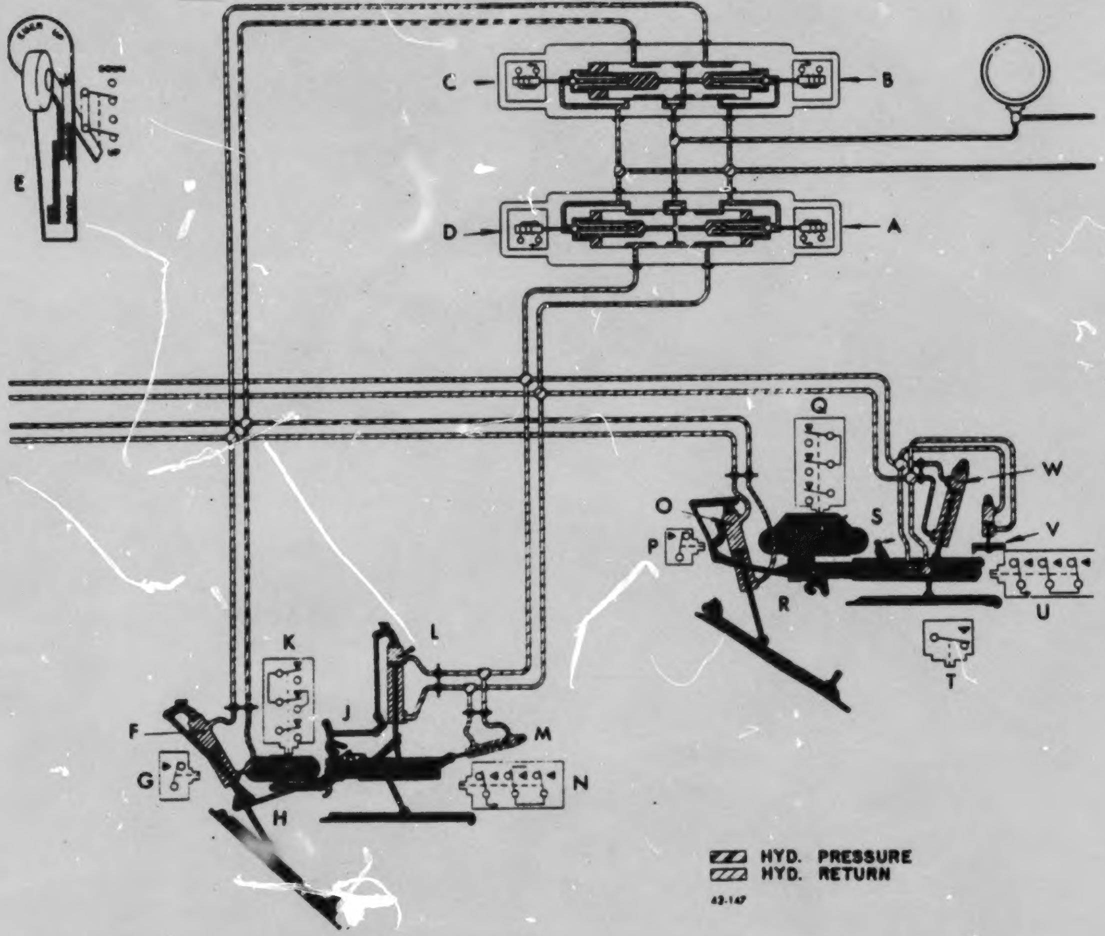
A. Extend gear solenoid
B. Door closed solenoid
C. Door open solenoid
D. Retract gear solenoid
E. Control handle
F. Door actuating cylinder
G. Gear up sequence switch
H. Door up-lock
J. Gear up-lock
K. Door sequence switch
L. Gear-actuating cylinder
M. Helper cylinder
N. Door sequence switch
O. Door actuating cylinder
P. Gear up sequence switch
Q. Door sequence switch
R. Door up-lock
S. Gear up-lock and cylinder
T. Ground safety switch
U. Door sequence switch
V. Gear down-lock and cylinder
W. Gear-actuating cylinder

Figure 40. Landing gear operation—control handle up, doors open, gear retracting.

remember, at the beginning of this section, we described a nonautomatic system as one in which full travel is required for each operation of the unit. We also said operators manually control the nonautomatic system. The automatic control system, or automatic position control system as the next section is titled, allows a variable application of hydraulic power. It provides smooth, control operation of a unit. Some automatic control systems, such as control surface boost systems and brake systems, incorporate "load feel."

11. Automatic Position Control Systems

11-1. These systems provide automatic control of actuating mechanisms such as nosewheel steering, control surface boost systems, and some wing flap systems. These systems have followup systems which limit the movement to a desired amount automatically. For example, when the manual control is moved a certain distance, the selector valve is positioned. Hydraulic pressure is directed to the actuating cylinder and it begins to move. The actuated



A. Extend gear solenoid
B. Door closed solenoid
C. Door open solenoid
D. Retract gear solenoid
E. Control handle
F. Door-actuating cylinder
G. Gear up sequence switch
H. Door up-lock

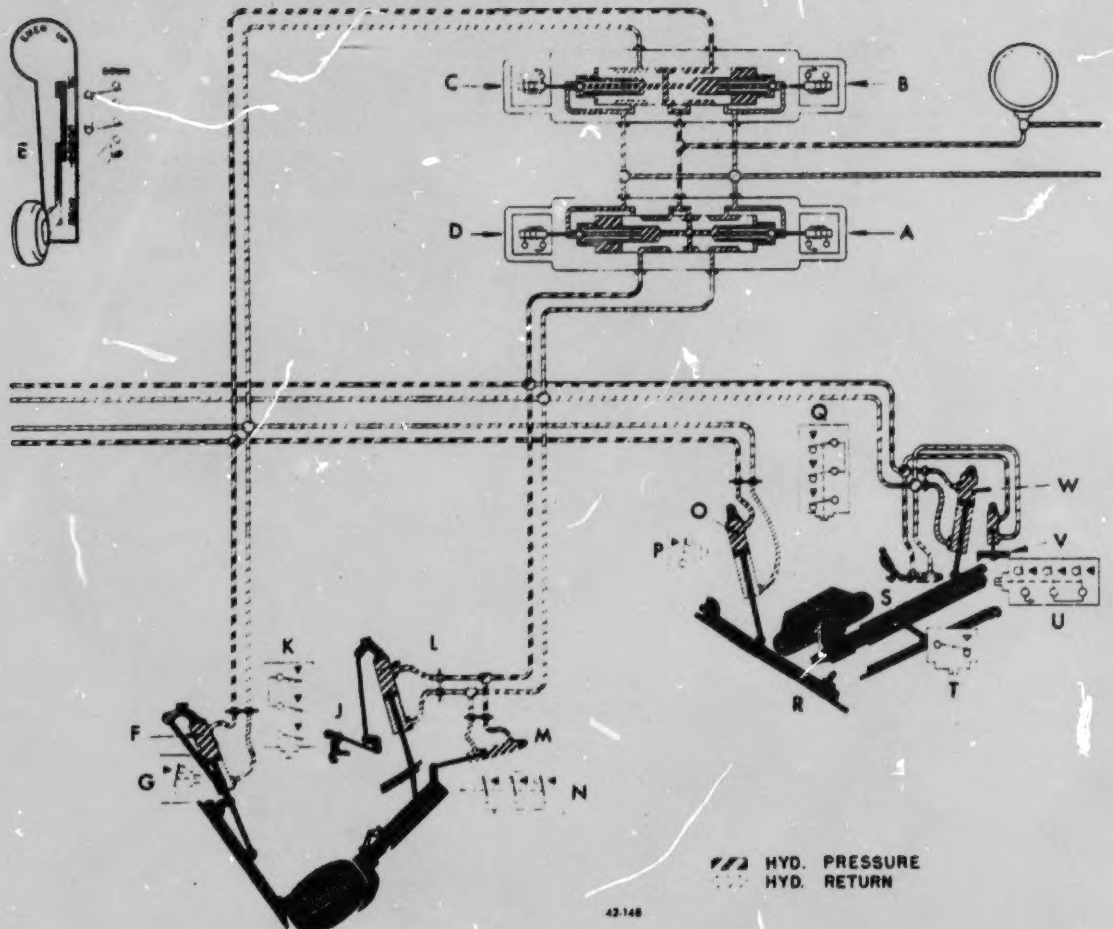
J. Gear up-lock
K. Door sequence switch
L. Gear actuating cylinder
M. Helper cylinder
N. Door sequence switch
O. Door-actuating cylinder

P. Gear up sequence switch
Q. Door sequence switch
R. Door up-lock
S. Gear up-lock and cylinder
T. Ground safety switch
U. Door sequence switch
V. Gear down-lock and cylinder
W. Gear-actuating cylinder

Figure 41. Landing gear operation—control handle up, gear up, door closing.

mechanism will move the amount called for on the manual control. At that point, the followup system will return the valve to neutral. This stops further movement and is done without any action on the part of the operator. As long as the manual control is being moved, it stays ahead of the followup action. This action keeps the selector valve in an operating (open) position. The followup mechanisms used on these systems may be either the mechanical type or the differential type.

11-2. **Mechanical-Type Followup System.** The mechanical-type followup system operates through a system of cables and pulleys or rigid linkage. Figure 44 represents a hydraulic flap system using a single mechanical linkage and a series of pivot points. This unit includes both a selector valve and an actuating cylinder. It is attached to a stationary part of the airframe (C). The pivot point for the control handle is at E. The control handle is connected to the selector valve by connecting rods. These connecting rods are anchored at one end to pivot point G. When the top of the control handle is moved to the left, the connector rod moves to the right. This will pull selector valve piston D to the right. The selector valve sends fluid pressure (represented by the solid line) to the right side



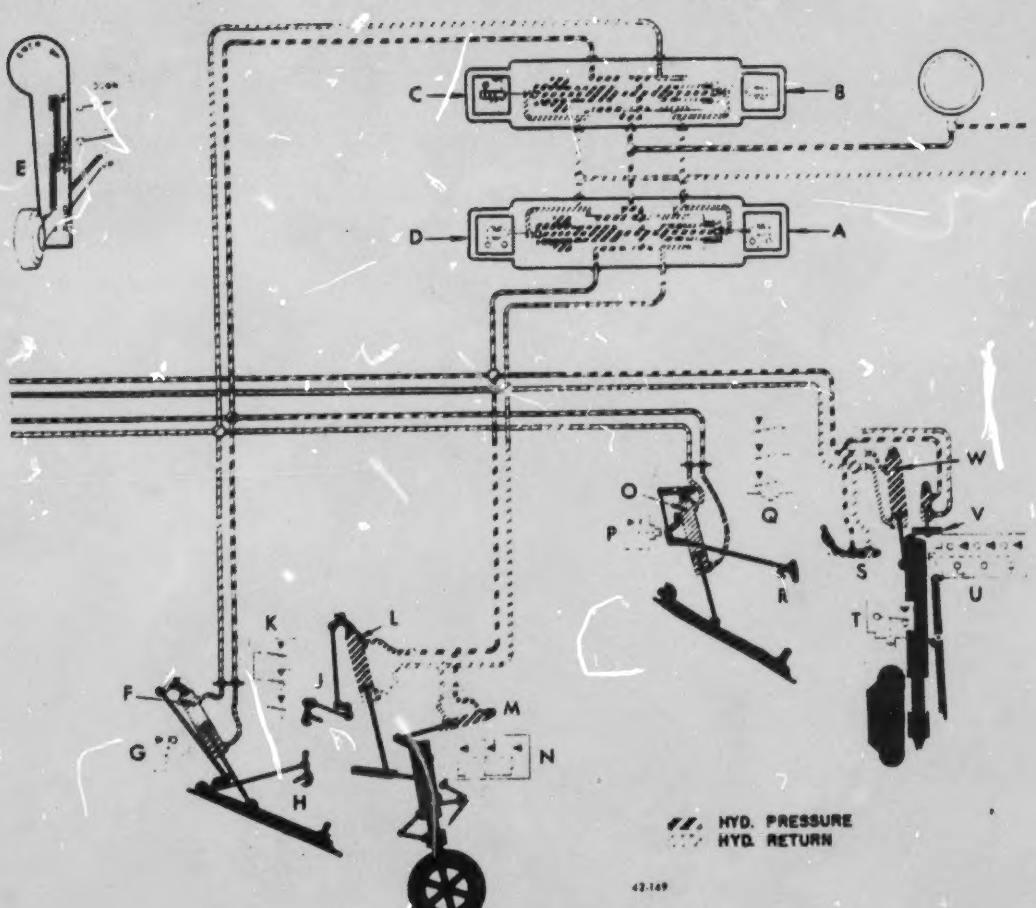
A. Extend gear solenoid
B. Door closed solenoid
C. Door open solenoid
D. Retract gear solenoid
E. Control handle
F. Door-actuating cylinder
G. Gear up sequence switch
H. Door up-lock
J. Gear up-lock
K. Door sequence switch
L. Gear-actuating cylinder
M. Helper cylinder
N. Door sequence switch
O. Door actuating cylinder
P. Gear up sequence switch
Q. Door sequence switch
R. Door up-lock
S. Gear up-lock and cylinder
T. Ground safety switch
U. Door sequence switch
V. Gear down-lock and cylinder
W. Gear-actuating cylinder

Figure 42. Landing gear operation—control handle down, doors opening, gear extending.

of actuating cylinder B. The pressure tries to move the piston to the left. The piston itself cannot move, since it is directly attached to the airframe. Therefore, hydraulic pressure moves the entire assembly (actuating cylinder and selector valve) to the right and this raises the flaps (A). When the movement of the control handle is stopped, pivot point F becomes stationary. However, point G moves with the total assembly. The assembly moves to the right, while the selector valve piston D stands still. This continues until both actuator ports are closed. The selector valve is now in neutral and cuts off pressure to the right side of the actuating unit. The flap movement is stopped.

11-3. The control handle may be placed in any position within its range of travel. Any movement of this control handle positions the selector valve and starts the actuating unit moving. The unit's movement over the piston is the followup system. When it moves the proportional amount, the selector valve is neutralized.

11-4. **Differential-Type Followup System.** The differential-type followup uses a set of opposed gears. The gears are inclosed in a separate housing from the actuating unit itself. Figure 45 shows a typical unit used on a nosewheel steering mechanism. Control handle



A. Extend gear solenoid
B. Door-closed solenoid
C. Door-open solenoid
D. Retract gear solenoid
E. Control handle
F. Door-actuating cylinder
G. Gear up sequence switch
H. Door up-lock
J. Gear up-lock
K. Door sequence switch
L. Gear-actuating cylinder
M. Helper cylinder
N. Door sequence switch
O. Door-actuating cylinder
P. Gear up sequence switch
Q. Door sequence switch
R. Door up-lock
S. Gear up-lock and cylinder
T. Ground safety switch
U. Door sequence switch
V. Gear down-lock and cylinder
W. Gear-actuating cylinder

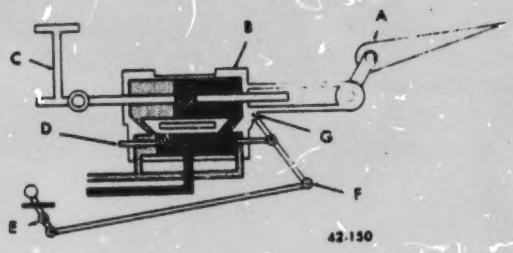
Figure 43. Landing gear operation—control handle down, gear down, doors closing.

A is attached directly to the manual control gear (B). The four gears in the differential are all meshed. The control gear meshes with two pinion gears (C).

11-5. As manual control handle A is rotated clockwise, the pinion gears *move around* the actuating mechanism gear (D). At this point in the operation of the differential unit, the actuating gear (D) remains stationary. The operating arm (H) is attached to the pinion gear cage and connects to a slide-type selector valve (G). When the pinion gears (C) move, the operating arm (H) moves also. It, in turn, moves the sliding spool of the selector valve (G).

11-6. This results in pressure being directed to one of the actuating cylinders (F). The cylinders (F) will turn the nose strut (E) to steer the airplane. However, when strut E turns, actuating gear D turns with it. This causes the pinion gears to walk around control gear B which is held stationary by input force on handle A. This action moves operating arm H in the opposite direction, neutralizing the selector valve action. This cuts off fluid flow to the actuating cylinder.

11-7. Continual movement can be achieved



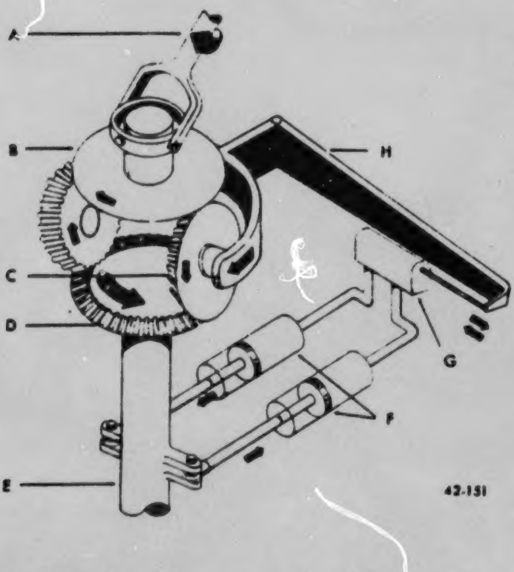
A. Control surface
B. Actuating cylinder
C. Airframe structure
D. Selector valve
E. Control handle pivot point
F. Pivot point
G. Pivot point

Figure 44. Mechanical type of position control.

by keeping the manual control moving ahead of the followup. As soon as the manual control is stopped, the followup motion will "catch up," neutralizing the selector valve. This stops the steering operation.

11-8. **Control Surface Boost Systems.** Aircraft control surfaces are subjected to extremely high airloads because of the high speeds. Surface boost systems aid the pilot in overcoming those air loads and reduce pilot fatigue.

11-9. A boost system provides sufficient power to move the control surfaces under maximum loads. Yet, it is designed to provide the pilot with "load feel" to help prevent overcontrol. In some systems the feel is supplied by springs attached to the linkage. In other systems the pilot gets load feel by manually supplying some of the force.



A. Control handle
B. Manual control gear
C. Pinion gears
D. Actuating mechanism gear
E. Nose gear strut
F. Actuating cylinders
G. Selector valve
H. Operating arm

Figure 45. Differential followup control

11-10. The system shown in figure 46 uses a slide-type control valve to direct hydraulic pressure to either end of the boost cylinder. The maximum boost pressure is limited by the amount of normal hydraulic system pressure available. The pilot gets load feel through mechanical linkage and by doing some of the work of moving the control surfaces. The pressure needed to move the control surface is proportional to the pilot's input. This is accomplished through the mechanical linkage arrangement. Therefore, this system has a fixed boost ratio. On some systems of this type, the linkage may be adjusted to change the boost ratio.

11-11. An arrow in figure 46 indicates the direction in which control stick A is initially moved. This movement causes the linkage to rotate around stationary pivot point B. The slightest motion of the control stick causes the slide piston of control valve D to move to the right. This allows fluid under pressure to be directed to the right-hand chamber of the actuating (boost) cylinder H. At the same time, pressure goes to line K to raise a plunger between the alternating lines.

11-12. The left end of piston rod E is relatively fixed by stationary pivot point F. Therefore, the entire valve and cylinder will move to the right. This action moves linkage G to operate the control surface. If the movement of control stick A stops, followup linkage J will catch up to it. At the same time, the movement of the valve and cylinder will catch up with the control valve rod movement. This neutralizes the control valve at that point. As a result, it blocks off hydraulic pressure to the boost cylinder.

11-13. While the system is operating, the two vertical portions of the linkage tend to move in opposite directions (as shown by the arrows). This is because of the force exerted by the hydraulic fluid in the boost cylinder. Feedback rod C limits this motion. It exerts a force on the right-hand vertical member of the linkage. This force is opposite to that force initially applied by the motion of the control stick. Thus, the operator feels a resistance to motion of the stick (load feel).

11-14. If hydraulic pressure were lost during flight, the mechanism could not be moved manually. This is because of the fluid trapped in each end of boost cylinder H. How is this remedied? In figure 46, you will notice a spring loaded plunger between the alternating lines. With no pressure to the boost system, the plunger is moved downward by the spring. This opens the passageway between the alternating

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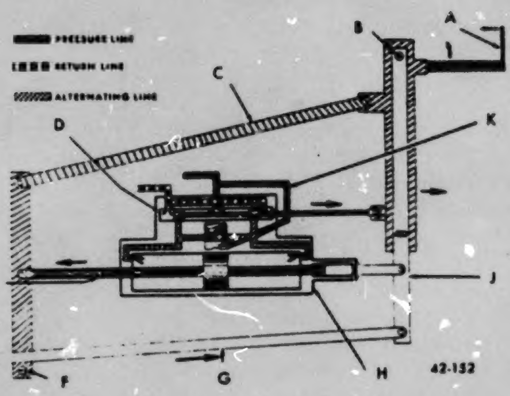


A. Control stick
B. Stationary pivot point
C. Feedback rod
D. Control valve
E. Boost cylinder piston rod
F. Stationary pivot point
G. Linkage to control surface
H. Boost cylinder
J. Followup linkage
K. Pressure line

Figure 46. Closed-center boost system.

lines. With this passage open, fluid can flow freely from chamber to chamber of the boost cylinder. Now the control surfaces can be operated manually.

11-15. The actuating systems we have covered so far are found in one form or another on all high performance aircraft. Yet, there are other actuating systems that are not so commonly used but are still important.

12. Miscellaneous Actuating Systems

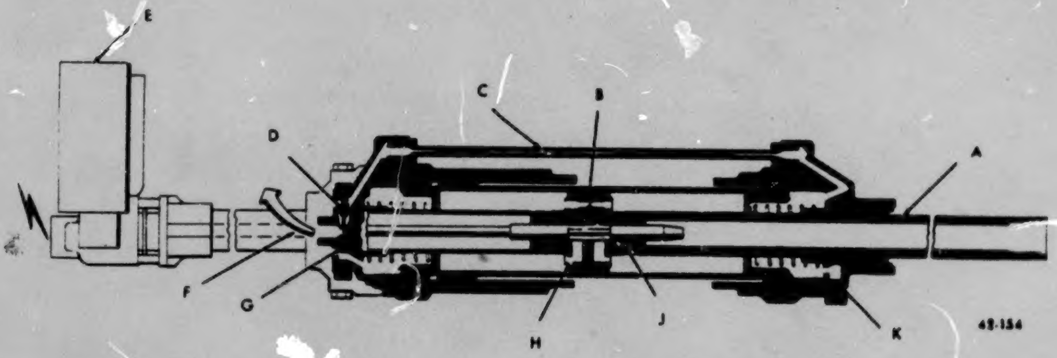
12-1. There are various hydraulic systems that are found only on certain model aircraft. For example, some aircraft use hydraulic pressure to actuate surface control locks. Some have pitch trim systems on their horizontal stabilizer. Other aircraft use slave systems to remotely control the actuation of a second hydraulic system.

12-2. **Control Lock System.** Control lock systems prevent fluttering of control surfaces by gusts of wind while the aircraft is on the ground. Figure 47 shows a hydraulically actuated surface control lock. The actuating cylinder is mounted to the aircraft structure at K. The cylinder piston rod (A) is attached to the control surface. Each control lock cylinder has its own reservoir and is independent of the main hydraulic system. The system is electrically controlled by an OFF-ON switch in the pilot's compartment. On propeller-driven aircraft, the locks are also actuated by placing the throttles in REVERSE.

12-3. The normal slipstream keeps the control surfaces streamlined, but during reversing operation the effect of the slipstream on the control surfaces is reduced. It may even whip the control surfaces around. Control locks are only used to keep the surfaces streamlined while on the ground.

12-4. Warning lights in the pilot's compartment indicate the position of the control locks. Each cylinder of the control lock is a balanced type. It incorporates a fixed orifice and a controllable valve within the piston (see fig. 47). The controllable locking valve (J) is opened and closed by an electric motor. The motor (E) is mounted on the end of the piston rod not fastened to the control surface. The contollable locking valve connects to the motor by a rod which is inside of the piston rod.

12-5. The operation of the control lock system is restricted to use only on the ground.



A. Piston rod (connected to control surface)
B. Fixed orifice
C. Interconnecting hydraulic line
D. Thermal valve (open)
E. Electric motor
F. Reservoir connection
G. Thermal valve (closed)
H. Interconnecting passageway
J. Controllable locking valve
K. Cylinder connection to airframe

Figure 47. Control lock cylinder.

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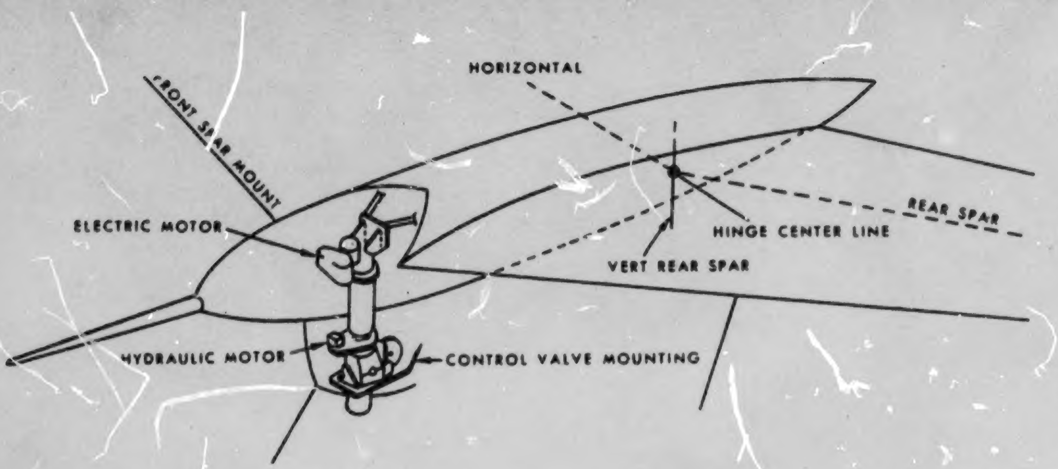

HORIZONTAL
FRONT SPAR MOUNT
ELECTRIC MOTOR
REAR SPAR
HINGE CENTER LINE
VERT REAR SPAR
HYDRAULIC MOTOR
CONTROL VALVE MOUNTING

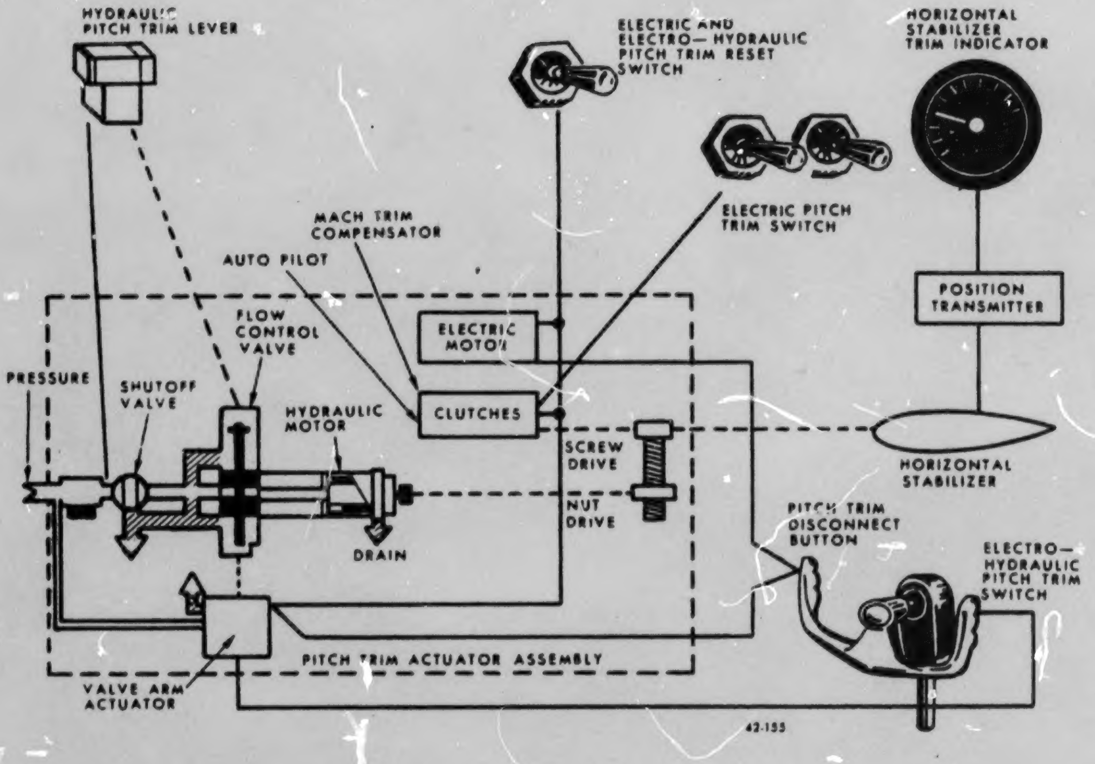

HYDRAULIC PITCH TRIM LEVER
ELECTRIC AND ELECTRO— HYDRAULIC PITCH TRIM RESET SWITCH
HORIZONTAL STABILIZER TRIM INDICATOR
ELECTRIC PITCH TRIM SWITCH
MACH TRIM COMPENSATOR
AUTO PILOT
POSITION TRANSMITTER
FLOW CONTROL VALVE
ELECTRIC MOTOR
PRESSURE
SHUTOFF VALVE
HYDRAULIC MOTOR
CLUTCHES
SCREW DRIVE
HORIZONTAL STABILIZER
NUT DRIVE
DRAIN
PITCH TRIM DISCONNECT BUTTON
ELECTRO— HYDRAULIC PITCH TRIM SWITCH
PITCH TRIM ACTUATOR ASSEMBLY
VALVE ARM ACTUATOR
42-155

Figure 48. Hydraulic pitch trim system.

The pilot's switch placed in the LOCKED position, or the throttles *reversed*, sends electric power to the motor. The electric motor causes the piston valve to move to the *closed* position. In this position, the valve blocks the main interconnecting passageway (H). Now, all fluid moving between the right and left cylinder chambers must pass through fixed orifice B. This dampens the movement of the control surfaces and prevents them from flapping during wind gusts. It allows only a slow, restricted movement. Placing the switch in the UNLOCKED position moves valve J to open passageway H. This allows unrestricted flow of fluid when the surfaces are being moved during flight.

12-6. A safety switch on the landing gear automatically unlocks the control locks upon takeoff. This is in case the pilot forgets to unlock them with his cockpit switch. This arrangement also prevents accidental locking of the controls during flight.

12-7. The chambers of the lock cylinder are connected by a small hydraulic line (C) on the outside of the cylinder. This interconnection is completed through thermal valve D. This insures that the cylinder chambers have a connection to the reservoir during fluid expansion or contraction. The reservoir provides space for this expansion or contraction.

12-8. The ends of thermal valve G are so arranged that both ends cannot be seated at the same time. However, this will not affect the normal function of the cylinder when it is in the locked position. This is because either end of the valve may be forced on its seat by fluid *surge*. A *slow* fluid movement will not do it. The reservoir is connected to the cylinder at port F. It may be mounted on the cylinder housing or on any other nearby aircraft structural unit. A periodic check must be made to determine the fluid level of the reservoir. The fluid level is indicated by a floating-type sight gage.

12-9. **Pitch Trim System.** The trim system is used to make minor correction in the aircraft's attitude. The system prevents the pilot from having to keep a continuous force on his controls. This could occur when the aircraft wants to fly nose high or low for some reason. Thus, it reduces the effort and strain on the pilot during a long flight.

12-10. The pitch trim system changes the angle of attack of the horizontal stabilizer. The changes correct for nose-high or nose-low aircraft attitude. The pitch trim system is a supplement to the elevator control. It is also completely independent of elevator control movement.

12-11. The system that we will discuss has the horizontal stabilizer attached at the top of the vertical stabilizer. However, it would also work if it were attached lower. The rear spar of the horizontal stabilizer is attached at a pivot point. This point is shown in figure 48. A jackscrew-type actuator is installed vertically near the leading edge. The *upper* actuator attach fitting is bolted to the forward spar of the *horizontal* stabilizer. The *lower* attach fitting is bolted to the forward spar of the *vertical* stabilizer.

12-12. The pitch trim system is operated by two completely independent drive systems. One is electromechanical and the other is hydromechanical. These are shown in figure 48. The electromechanical drive unit is located on the top of the actuator assembly. An electric motor is used to drive it. The electric motor, through a gear train, *rotates the jackscrew*. This mechanism is used for minor changes.

12-13. The hydromechanical drive unit is located on the bottom of the actuator assembly. A hydraulic motor is used for the drive unit. The hydraulic motor, through a gear train, *drives a rotating nut*. The rotating nut cannot move vertically. Therefore, as the nut rotates, the jackscrew will move up or down, depending on the direction of rotation. The hydraulic drive is approximately five times faster than the electric motor operation.

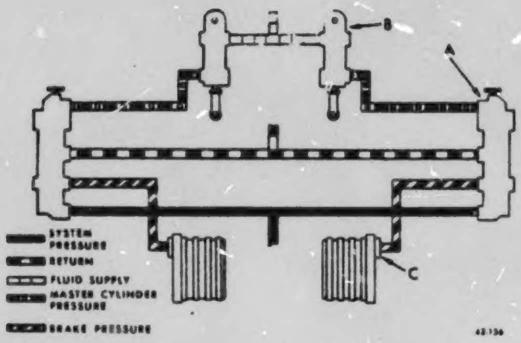
12-14. The hydraulic system consists of: the hydraulic motor, flow control valve, solenoid shutoff valve, filter, and a valve arm actuator. Hydraulic pressure (see fig. 48), is supplied to the valve arm actuator and through a filter to the solenoid shutoff valve. The solenoid shutoff valve is energized to the CLOSED position. When the valve is deenergized, it opens and supplies fluid to the flow control valve. The flow control valve can be operated mechanically by the pitch trim lever in the cockpit. The lever is connected to the flow control valve by cables. The valve arm actuator is mechanically connected to the flow control linkage at the same point. This actuator is electrically activated by the pitch trim switches on the control wheel. This allows electrical positioning of the flow control valve. Thus, the hydraulic pitch trim can be activated manually and electrically.

12-15. When fast operation of the pitch trim system is desired, it is operated hydraulically. For fine adjustment or autopilot control, the system is driven electrically.

12-16. **Hydraulic Slave System.** Hydraulic slave systems are used on aircraft to reduce weight. A slave system is an independent system used to operate remotely located hydraulic units energized by the main system. An example is the power brake control valve. The control valves are located a great distance from the pilot. With a master cylinder, the pilot remotely positions the power brake control valve. A master cylinder slave system is shown in figure 49.

12-17. Master cylinder B forces a small volume of fluid under pressure to the slave cylinder through a small line. As the piston in the slave cylinder moves, it positions power brake control valve A. The power brake control valve then directs system pressure to brake units C.

12-18. Now that we have finished the miscellaneous systems, let us think back for a



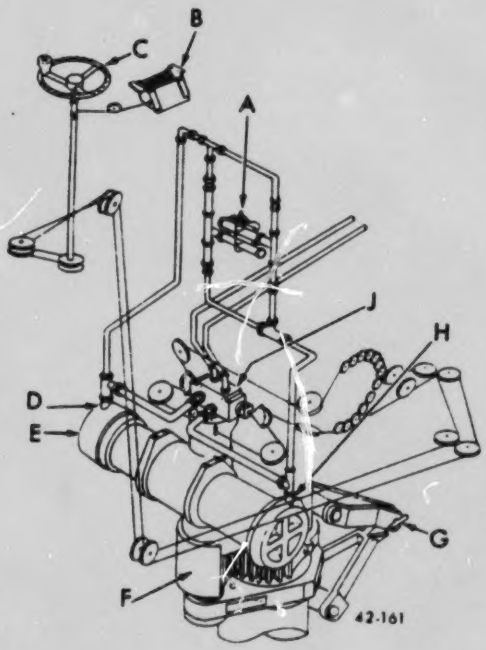
A. Power brake valve B. Master cylinder C. Brake unit

Figure 49. Master cylinder slave system.

moment to paragraph 11-4 which introduced the differential-type followup system. There, you learned about the followup device in an automatic position control system. You will now have the opportunity to study the entire system.

13. Hydraulic Steering Mechanisms and Controls

13-1. High performance aircraft with tricycle landing gear ordinarily have a nosewheel steering mechanism. This type of steering has many advantages over the older methods. The older techniques were either applying alternate brakes or gunning alternate engines. The older method of steering caused excessive wear on the brakes and tires. In multiengine aircraft, gunning opposite engines sometimes results in excessive taxiing speeds. Nosewheel steering eliminates this and requires less attention or effort by the pilot.



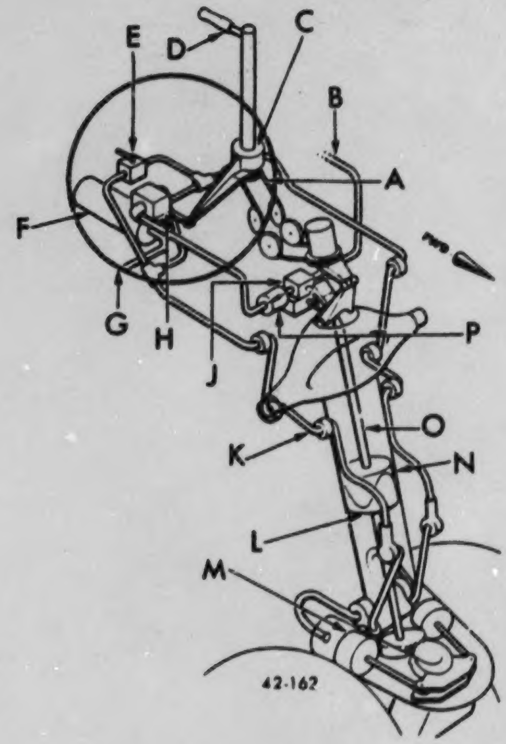
A. Relief and check arrangement valve
B. Steering indicator
C. Steering wheel
D. Right turn inlet port
E. Steering actuator
F. Interconnecting terminal gears
G. Torque link quick disconnect
H. Left turn inlet port
J. Steering control valve

Figure 50. Nosewheel steering (rack and pinion actuator).

13-2. There are three main types of steering mechanisms: the rack and pinion actuator, actuating cylinders with a differential followup system, and the steering damper type. This last type contains a unit which acts as a damper when the steering mechanism is not in use.

13-3. **Rack-and-Pinion-Type Steering Mechanism.** This type of mechanism is hydraulically operated and mechanically controlled by cable rigging (see fig. 50). To get hydraulic pressure to the actuator, the steering switch must be engaged and the gear safety switches compressed. With the steering switch engaged, a shutoff valve (not shown) allows fluid to flow to the steering control valve (J). The steering control valve is rigged to the pilot's steering wheel (C). It controls the system pressure to the steering rack and pinion actuator (E). As the pilot steers, the directional control valve moves from its neutral position. This directs pressure to the proper side of the actuator. It is an open center valve—that is, when in neutral it throughpasses fluid pressure to the return line. The actuator then turns the nosewheel through interconnecting terminal gear F. As the nosewheel turns, the followup arrangement returns the control valve to its neutral position. Excessive pressures in the alternating lines (D and H) are prevented by a relief and check valve arrangement (A). If the steering switch is off, the aircraft may be towed or taxied without hydraulic restriction in the actuating cylinder. This can be done because of the open-center throughpass construction in the control valve. As a safety precaution the torque links should be disconnected during towing of the aircraft. A quick-disconnect arrangement (G) serves this purpose. Steering indicator B tells the pilot the position of his nosewheel while steering is engaged.

13-4. **Steering Mechanism with Two opposing Actuating Cylinders.** In figure 51, we see that the two opposing cylinders (M) turn the nosewheel in either direction. Directional metering valve H directs pressure to the proper cylinder. As you move steering handle D, differential unit C moves. Through mechanical linkage, it positions metering valve H. Fluid



A. Followup system control cable
B. Pressure line
C. Differential unit
D. Steering handle
E. Emergency or bypass valve
F. Compensator
G. Return line
H. Metering valve
J. Shutoff valve (operated by oleo strut extension)
K. Swivel joint
L. Centering cam (stationary)
M. Actuating cylinder
N. Centering cam (moves with orifice rod)
O. Orifice rod
P. Check valve

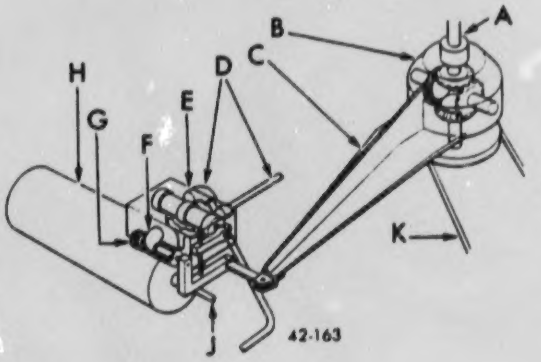
Figure 51. Nosewheel steering (differential actuation).

then is metered out to one of the actuating cylinders.

13-5. An orifice and orifice rod O play an important part in the operation of the steering action. The orifice rod is connected to the bottom of the strut interior. The rod moves up or down with the lower part of the strut. When the weight of the aircraft is on the gear, the orifice rod extends through an orifice on the top of the strut. There it strikes a roller which actuates the nose steering shutoff valve J, opening it. This allows fluid from the pressure line B to flow through check valve P to metering valve H. An emergency or bypass valve (E) allows hydraulic fluid to flow freely from one actuating cylinder to the other. This valve is opened when the aircraft is to be towed. It can be either mechanically or electrically operated, depending upon the type of aircraft on which it is installed. The opening of the valve bypasses the metering valve, thereby making the nosewheel steering system inoperative.

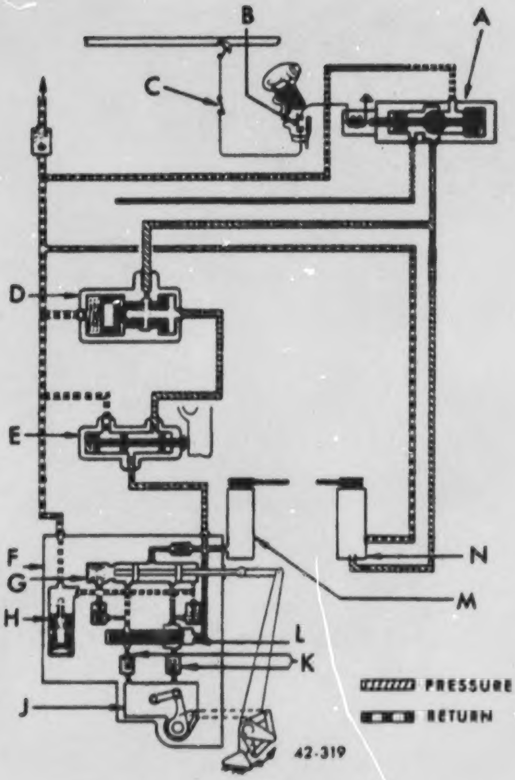
13-6. Centering cams L and N aline the nosewheel fore and aft when the strut is fully *extended*. This insures proper alinement for retraction and also for landings. Figure 51 shows the position of the centering cams when the strut is extended. Upper cam N is fastened to the orifice rod; therefore, it moves up and down with it. The bottom cam is fastened to the strut; therefore, it does not move. When the weight of the aircraft is placed on the gear, the centering cams disengage. Swivel joints K act as hinges in the alternating lines when the gear is retracted.

13-7. The differential, figure 52, also plays an important part in the operation of the steering system. Movement of steering control A (item D, fig. 51) rotates the top gear in differential B (item C, fig. 51). The bottom gear is held stationary by the followup system control cable K (item A, fig. 51). The two side gears move around the bottom gear, causing motion of differential actuating arm C. Movement of the operating arm causes positioning of the metering valve E (item H, fig. 51). The metering valve is held in a neutral position by centering spring G when not in operation. When the metering valve is moved, fluid



A. Steering control
B. Differential
C. Differential actuating arm
D. Line to actuating cylinders
E. Metering valve
F. Pressure line
G. Valve centering spring
H. Compensator
J. Return line
K. Followup system control cable

Figure 52. Differential system.



A. Solenoid shutoff valve
B. Switch (pushbutton type)
C. Nose gear load switch
D. Pressure-reducing valve
E. Safety shutoff valve
F. Steering damper unit
G. Nosewheel steering selector valve
H. Compensator unit
J. Actuating cylinder
K. Orifice check valves
L. Internal bypass valve
M. Pressure-operated clutch
N. Interconnect clutch

Figure 53. Nosewheel steering (steering damper actuation).

pressure is sent to the respective actuating cylinder. Movement of the nosewheel in either direction will rotate the orifice rod. This movement rotates the bottom gear of the differential through the followup system control cable K. Rotation of the bottom gear moves actuating arm C, which returns the selector valve to neutral.

13-8. The compensator H (item F, fig. 51) is a piston-type accumulator. It maintains a minimum amount of pressure for shimmy damping during taxiing when the selector valve is in a neutral position. The other callouts in figures 51 and 52 are self-explanatory.

13-9. **Steering Damper Mechanism.** This system, shown in figure 53, provides steering of the aircraft and shimmy damping action. The system includes the steering damper unit (F), a pressure-reducing valve (D), an interconnect clutch (N), and two shutoff valves (A and E). Normal system pressure is directed to the solenoid-operated shutoff valve (A). This valve opens only when the nose gear shock strut is compressed and closes switch C. Button B on the pilot's control stick must also be pressed to complete the circuit to the solenoid.

13-10. When the solenoid-operated shutoff valve is energized and open, hydraulic pressure is directed to pressure-reducing valve D. Pressure also is directed to interconnect clutch N. The clutch hydraulically connects the rudder cable movements to the nosewheel steering system. This allows steering motion to come directly from the rudder pedals. The clutch disengages the rudder cables from the steering systems when pressure is off the steering system.

13-11. Pressure-reducing valve D reduces the system pressure to the operating pressure for the steering damper unit. Fluid flows from the pressure reducer to safety shutoff valve E. The safety shutoff valve is mechanically opened when the nose gear is down and the strut is compressed. From the safety valve, fluid goes to damper unit F.

13-12. Steering damper unit F is a combination selector valve, actuating cylinder, and shimmy damper. A pressure-operated clutch (M) engages the cable-operated pulley to the selector valve through the followup mechanism. When pressure is directed to the steering unit, clutch M engages and, at the same time, internal bypass valve L closes. This bypass valve, when closed, prevents free flow of fluid from one side of the actuating piston to the other.

13-13. Movement of selector valve G sends fluid through restrictor valves K to actuating cylinder J, thus turning the nosewheel. As this happens, the followup linkage repositions the selector valve to the neutral position. The repositioning of the selector valve to the neutral position stops any further turning of the nosewheel. To turn it farther, the selector valve must be repositioned again.

13-14. Compensator unit H maintains a slight pressure in the steering unit when the selector valve is in neutral. This pressure prevents cavitation of the steering actuating cylinder. This can happen when the nosewheel is suddenly turned by external shock loads. The compensator consists of a small spring-loaded piston with a built-in relief valve set at about 75 psi. Another function of the compensator relief valve is to prevent excessive pressure caused by thermal expansion. When the hydraulic pressure for steering is released, clutch M disengages and bypass valve L opens. When this happens, the steering unit becomes a shimmy damper. Orifice check valves K prevent rapid shimmy of the nose gear. They restrict the fluid flow from one side of the actuator cylinder to the other.

13-15. Electrical Followup-Nose Wheel Steering. We have learned that mechanical-type followup systems operate through a system of cables and pulleys or rigid linkage, and the differential-type followup system uses a set of opposed gears. Electrical followup is accomplished by varying the voltage in the two potentiometers.

13-16. The input potentiometer is located above the nose strut and is operated by movement of the rudder pedals. The followup potentiometer is located on the steering power unit and is operated when the wheel turns.

Aircraft Emergency Pneudraulic Systems

AIRCRAFT EMERGENCY hydraulic systems on various aircraft operate different units. Emergency systems operate only the essential components needed for mission completion or safety. The methods used to operate them vary greatly; they depend on the aircraft's needs. These systems can be pressurized by hand pumps, electrically driven pumps, and fluid or air stored under pressure. Working in conjunction with the emergency systems are warning devices that indicate when the emergency system should be used. We shall discuss these different systems and show how they are used.

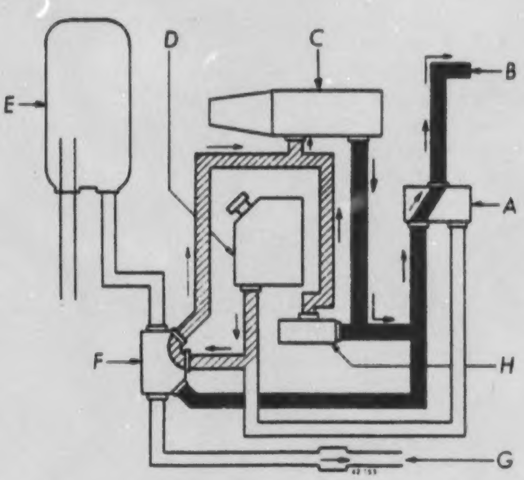
14. Emergency Flight Control Operation

14-1. Operation of the flight controls is essential to flight. Effective operation of flight controls on some aircraft is more critical than on others; these incorporate an emergency hydraulic system for the flight controls. The other aircraft rely upon manual override operation when the normal system fails. So that you have an understanding of emergency systems, we will first discuss the arrangement of a basic electrically operated emergency system. Next, we will look at a specific emergency system: the wing flap system. Finally, we will examine the use of a backup hydraulic system for emergencies.

14-2. **Electrically Operated Emergency System.** Some aircraft use an electrically driven emergency pump. This pump usually has a much smaller output volume than the normal engine-driven pump. It is not considered practical for normal use. The primary purpose is to operate certain subsystems when the main system fails. Its secondary purpose is for ground testing the main system through line G, shown in Figure 54. This figure shows the direction of fluid flow through an emergency system while it is in operation.

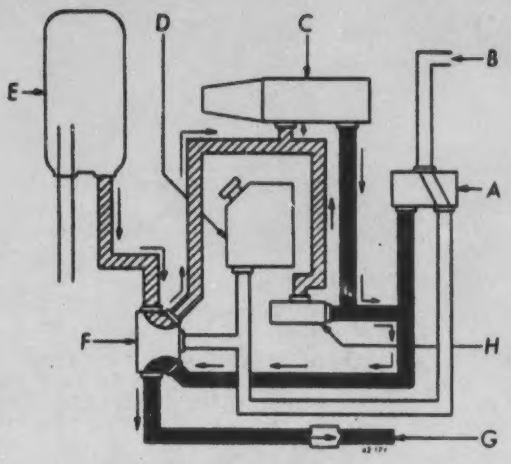
14-3. Notice the two reservoirs (D and E) in this system. Emergency pump C can draw fluid from either reservoir, depending upon the position of ground test selector valve F. Figure 54 shows the ground test selector valve in the INFLIGHT position. The valve should be kept in this position at all times, except during ground testing. When the emergency pump is operated, it will draw fluid from the emergency reservoir. From the pump, fluid goes to emergency selector valve A. Then it goes to its applicable subsystems through emergency pressure line B. The only pressure-limiting device in this case is the small relief valve (H).

14-4. Figure 55 shows the system in ground test position and using the main system reservoir (E). The ground test selector valve (F) in figure 55 has been set at the GROUND TEST position. Notice also that fluid leaving the emergency pump (C) cannot go through



A. Emergency selector valve
B. Emergency pressure line
C. Emergency system pump
D. Emergency reservoir
E. Main system reservoir
F. Ground test selector valve
G. Ground test line to normal system pressure manifold
H. Relief valve

Figure 54. Emergency system—emergency conditions.



A. Emergency selector valve
B. Emergency pressure line
C. Emergency system pump
D. Emergency reservoir
E. Main system reservoir
F. Ground test selector valve
G. Ground test line to normal system pressure manifold
H. Relief valve

Figure 55. Emergency system—ground test condition.

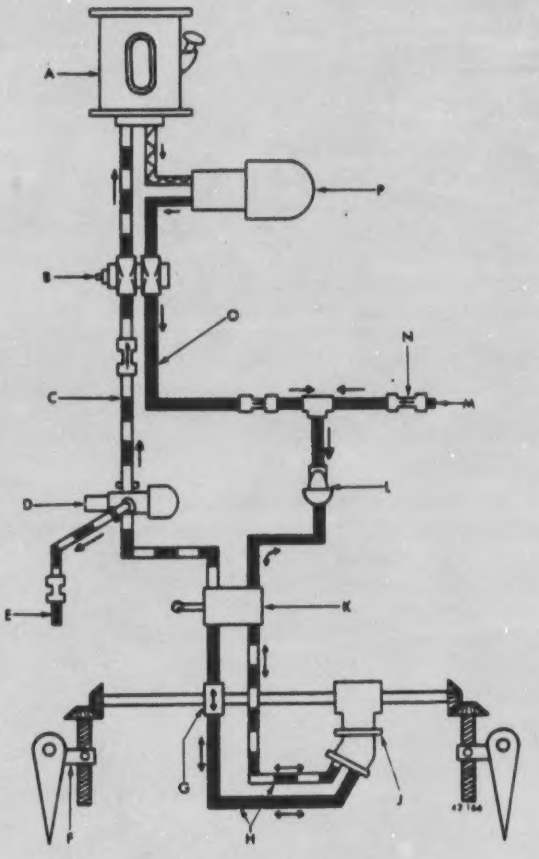
emergency selector valve A. Therefore, the fluid leaving the emergency pump must go through the ground test selector valve. Here it enters the normal system pressure manifold line (G). Emergency selector valve A is positioned so that emergency pressure line B is connected to the emergency reservoir. This is called the normal position of this valve. Should the fluid in line B expand due to a thermal buildup, it can expand into reservoir D. This also prevents this thermal pressure from shifting the shuttle valves to the emergency position. This is not wanted during normal operation.

14-5. **Emergency Wing Flap System.** The system shown in figure 56 has only one purpose. This is to provide hydraulic pressure for operation of the wing flaps in case the main system fails. Use of wing flaps is necessary for safe landings.

14-6. In figure 56, main system pressure is supplied to the flap system through pressure inlet line M. Main system pressure goes through filter L and control valve K before it goes to motor J. The check valves in the pressure lines prevent fluid transfer to the emergency system. Control valve K directs fluid through one of the two alternating lines H to flap hydraulic motor J. The direction of flow through the flap motor (as determined by the control valve position) governs the direction in which the flaps moves.

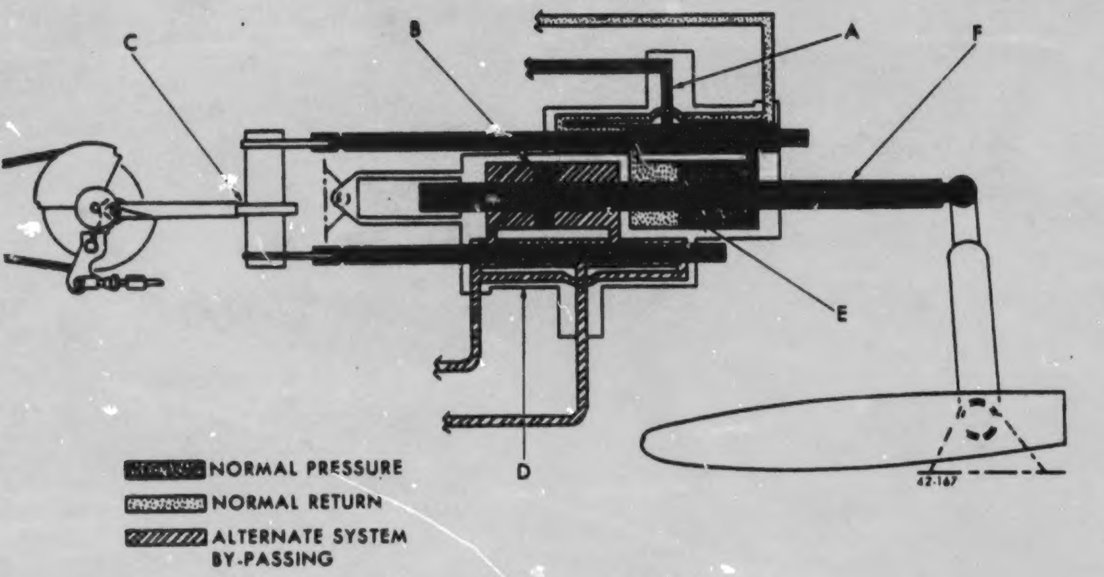
14-7. The motor rotates the drive gears, which rotate the jackscrew and move the flaps (F). The hydraulic motor's return fluid goes through the control valve. From the control valve, the fluid goes to the electrically controlled shuttle valve (D). During normal or main system operation, shuttle valve D is deenergized. Fluid flowing from the control valve is directed to main system return line E.

14-8. When the normal system in figure 56 fails, electrical power is applied to both



A. Emergency flap reservoir
B. Relief valve
C. Emergency system return line
D. Electrically operated shuttle valve
E. Main system return line
F. Wing flap and jackscrew
G. Restrictor
H. Alternating line
J. Flap actuator (hydraulic motor)
K. Control valve
L. Filter
M. Main system pressure line
N. Check valve
O. Emergency system pressure line
P. Emergency system pump and pump motor

Figure 56. Emergency wing flap system.



A. Normal system metering valve
B. Alternate system actuating piston
C. Metering valves positioning mechanism
D. Alternate system metering valve
E. Normal system actuating piston
F. Common piston rod

Figure 57. Flight control power unit.

emergency pump P and shuttle valve D. With the emergency pump operating, fluid is drawn from emergency reservoir A. The pump sends it to flap control valve K.

14-9. Notice check valve N in the normal pressure line. It prevents emergency pressure from escaping into the normal line. The pressure-limiting device during emergency operation is relief valve B. After the control valve is positioned and the flaps are moved, the return fluid will seek a path to return. Since shuttle valve D is energized, the returning fluid is directed into emergency return line C. From there, it flows back to the emergency reservoir. Thus, no emergency fluid should be lost if both systems are working properly. Restrictor G limits the flow through motor J in both directions.

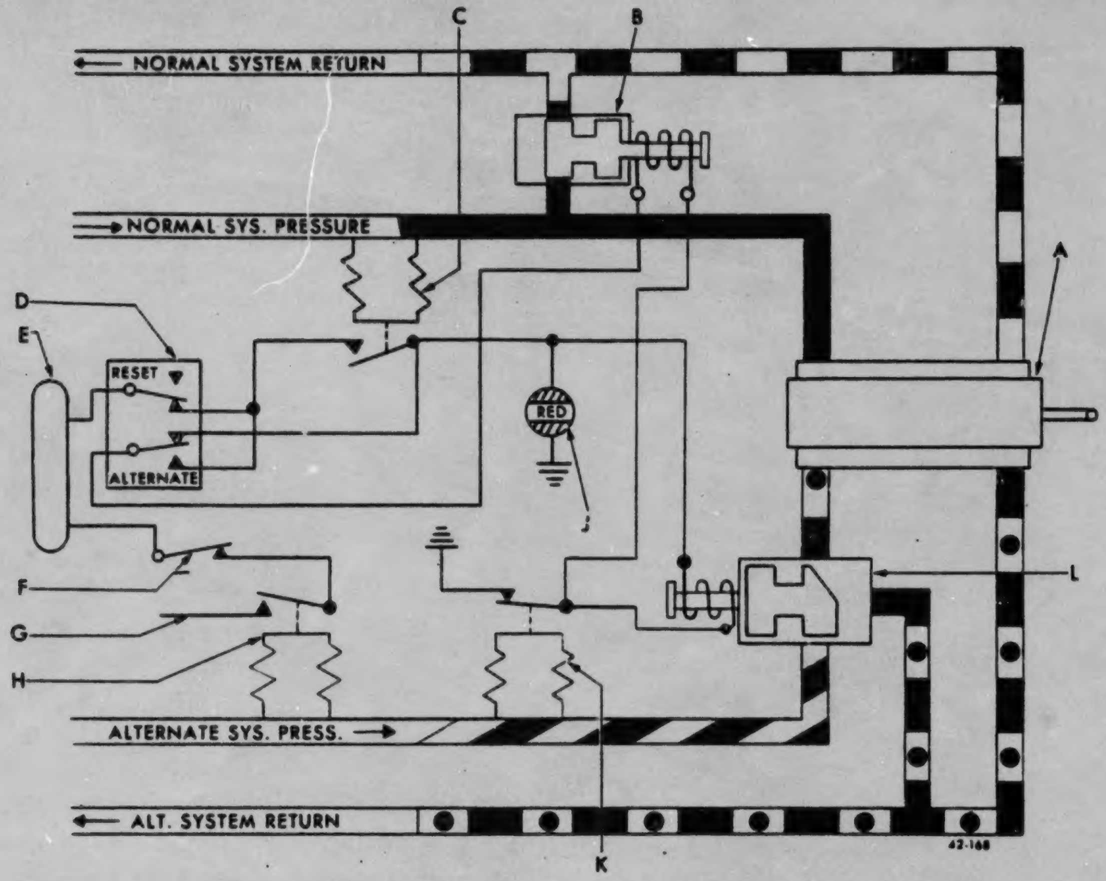
14-10. **Combination Normal and Alternate System.** Some models of aircraft have two independent hydraulic systems to actuate the flight controls. In such installations, the flight controls are normally actuated by the "normal" or "main" system. If the normal system fails, then the alternate system will automatically assume control.

14-11. Figure 57 shows a flight control power unit which is actuated by a dual system such as described above. Unlike most emergency systems, the alternate pressure does not enter the normal actuator through a shuttle valve. Both the normal and the alternate systems have separate selector valves and actuating cylinders.

14-12. In figure 57, notice that the two metering valves (A and D) are positioned together. This is done by moving the control stick which is attached to the positioning mechanism (C). The cylinder arrangement is such that both pistons B and E drive the same piston rod F. Through this arrangement, the normal and alternate systems are kept completely independent.

14-13. Now, with the help of figure 58, let us see when and how fluid enters the system. Item A represents the control surface power unit, illustrated in figure 57. Alternate pressure can energize control surface power unit A through alternate system shutoff valve L. The alternate system *automatically* provides the necessary operating pressure when normal pressure is below desired setting. Pressure switch C, located in the normal system pressure line, energizes the emergency system. Should normal system pressure fail, pressure switch C would close to complete a circuit that makes the changeover.

14-14. Let's see what happens when the normal system pressure drops, thereby causing changeover switch C to close. Power for system operation is supplied by bus E. From the bus, current goes to the upper points of control



A. Control surface unit
B. Normal system bypass valve
C. Normal system pressure switch
D. Emergency hydraulic control switch
E. 24-volt bus
F. Alternate system pump switch
G. Wire to alternate pump motor
H. Alternate system pump pressure switch
J. Red warning light
K. Alternate system pressure switch
L. Alternate system shutoff valve

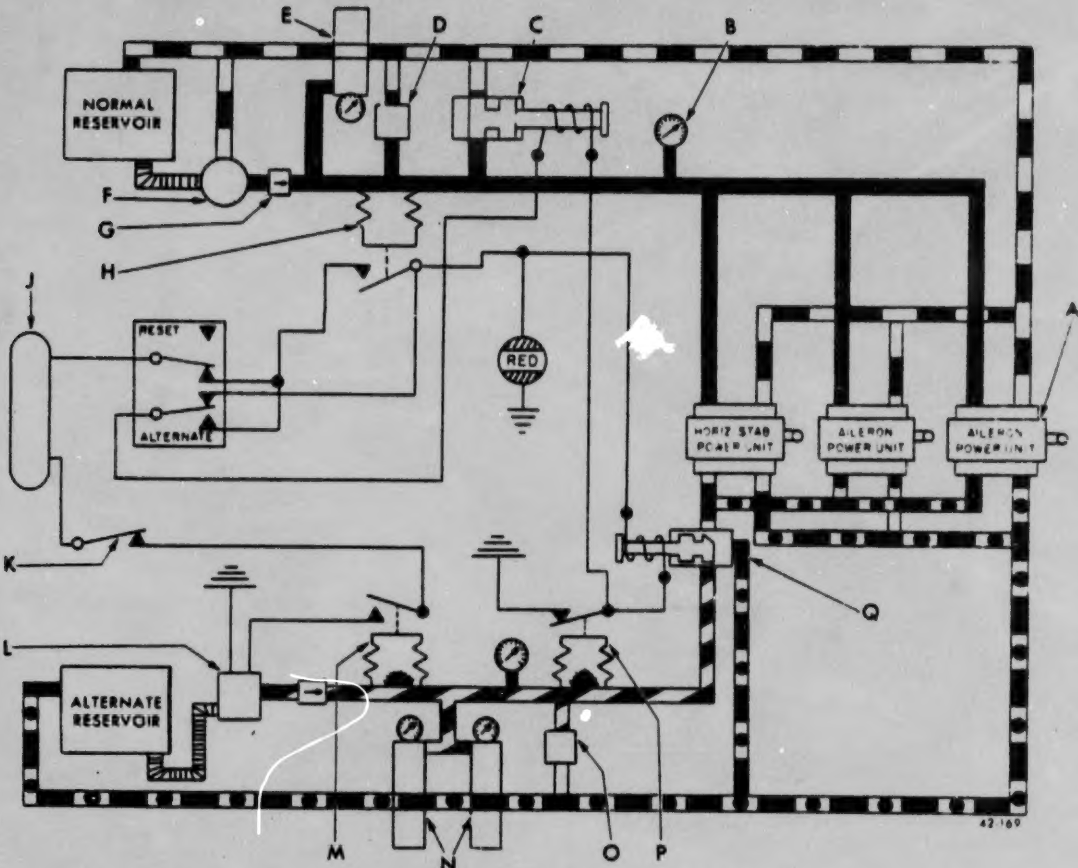
Figure 58. Flight control hydraulic system electrical circuit.

switch D. Pressure switch C has closed and now provides a path for current flow back to the lower points. From the lower points of control switch D current goes through bypass valve B and on to ground through pressure switch K. If pressure switch K is closed, it provides the ground for the alternate system. Now, normal system bypass valve B is energized open. It vents all remaining pressure in the normal system to the normal return line. At the same time, a circuit starting at closed switch C energizes the red warning light J. It continues on to open alternate system shutoff valve L. The warning light has its own ground. Alternate system shutoff valve L is also grounded through pressure switch K. Using pressure switch K as the path to ground makes sure that changeover cannot be made unless there is ample pressure in the alternate system.

14-15. Pressure switch H is used to regulate the pressure in the alternate system. It controls the circuit to the alternate system pump motor through alternate motor wire G. Toggle switch F is normally closed during flight. It can be turned off at will.

14-16. Emergency hydraulic control switch D provides for manual changeover at any time. Let us assume that you wish to check the alternate system to see if it is operating properly. Pressure switch C is normally open, so you must in some way bypass this switch to perform the test. This bypass must complete a circuit around the open switch C. You can bypass it by moving the lower toggle in the emergency hydraulic control switch to the ALTERNATE position.

14-17. With the toggle placed in the ALTERNATE position, current flows from the bus bar to the upper toggle. From the upper toggle, it flows through the lower toggle, and



A. Control surface power units
B. Normal system pressure gage
C. Normal system bypass valve
D. Normal system relief valve
E. Normal system self-displacing accumulator
F. Engine-driven pump (for normal system)
G. Check valve
H. Normal system pressure switch
J. 24-volt bus
K. Alternate system manually operated switch
L. Alternate system pump
M. Alternate system pump pressure switch
N. Alternate system self-displacing accumulator
O. Relief valve
P. Alternate system pressure switch
Q. Alternate system shutoff valve

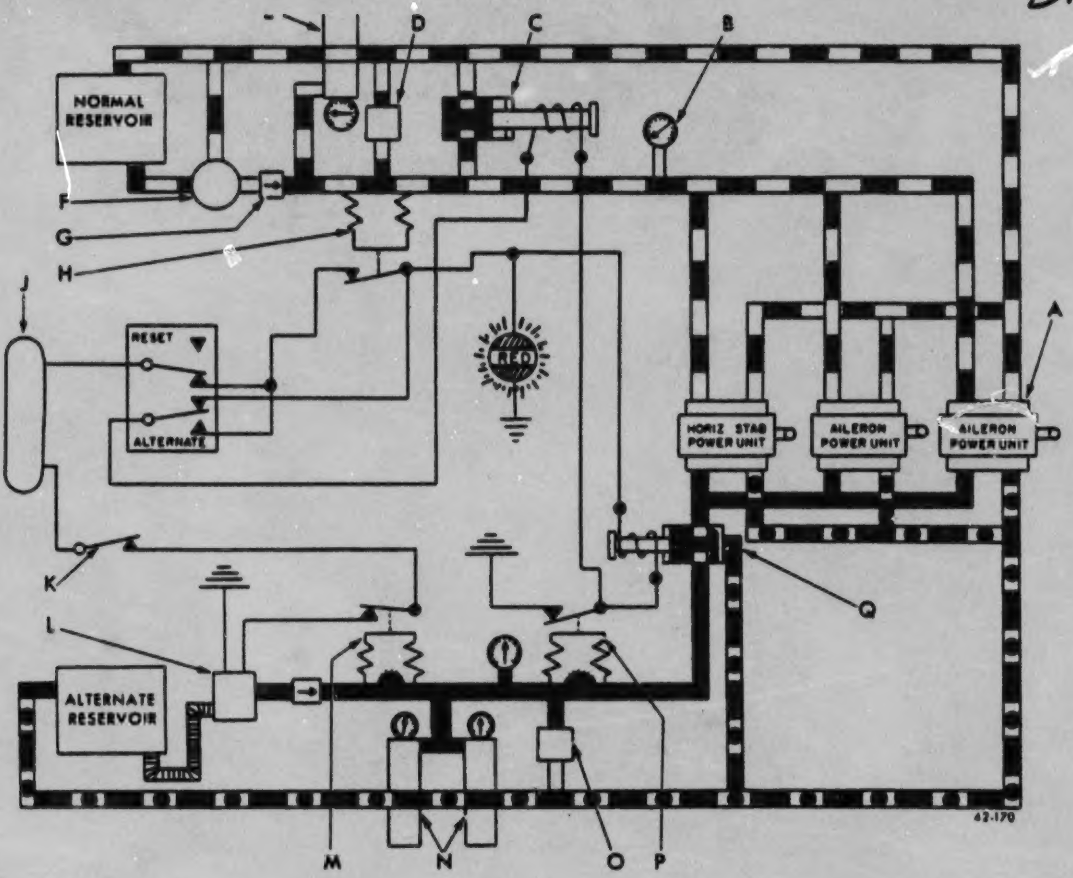
Figure 59. Flight control hydraulic system—normal operation.

then to normal bypass valve B. As the bypass valve opens, the normal system pressure is dumped into the return manifold. When the normal system pressure drops low enough, pressure switch C closes. This completes the circuit to the light and the alternate system shutoff valve, thus completing the changeover. To change back to normal system, you must return the lower toggle to its normal position. Then momentarily raise the upper toggle to the RESET position. The RESET position merely breaks the circuit to all of the electrical units. This allows them to spring back to their normal closed position.

14-18. Figures 59 and 60 show the same system as figure 58 but in more detail and completeness. Figure 59 shows the position of all switches and valves while the normal system is in operation. Notice that pressure switch M, which controls the alternate system pressure, is open. This indicates that the alternate system pump L is not running. Alternate system pressure is available in the lines and accumulators N. If the alternate pressure should drop off slightly, pressure switch M would close and send current to pump motor L. When the pressure again builds up to the desired value, the contact through the pressure switch will be broken. Through the opening and closing of this switch, alternate system pressure is maintained at a predetermined setting.

switches and valves while the normal system is

14-19. Pressure switch P remains closed unless pressure drops so low that it cannot



A. Control surface power units
B. Normal system pressure gage
C. Normal system bypass valve
D. Normal system relief valve
E. Normal system self-displacing accumulator
F. Engine-driven pump (for normal system)
G. Check valve
H. Normal system pressure switch
J. 24-volt bus
K. Alternate system manually operated switch
L. Alternate system pump
M. Alternate system pump pressure switch
N. Alternate system self-displacing accumulator
O. Relief valve
P. Alternate system pressure switch
Q. Alternate system shutoff valve

Figure 60. Flight control hydraulic system—alternate operation.

operate the control surfaces. Its primary purpose is to prevent a changeover unless there is ample pressure in the alternate system. Pressure switch H in the normal system is open because there is sufficient pressure in that system for normal operation. Check valve G prevents backflow through pump F which would motorize the pump. This could happen if excess pressure built up in the normal system pressure lines.

14-20. Units included in the normal system and which have not been mentioned in the above discussion are: pressure gage B, relief valve D, accumulator E, pump F, and the normal system reservoir. With the exception of the accumulator, these units operate the same in this system as in any other hydraulic system. The emergency or alternate system also includes the same units.

14-21. Figure 60 shows the control surfaces being operated by the alternate system. What you have learned from figure 59 can be transferred to the operation shown in figure 60. Notice that both normal system bypass valve C and alternate system shutoff valve Q are open. This allows any fluid in the normal system to have a path to the return manifold. Also, it provides a path for alternate system pressure to the units. These valves are held in their positions by electrical energy. If the electricity should fail, the valves would spring closed.

14-22. The hydraulic systems in some fighter aircraft do not depend on electrical power for emergency pump operation. Instead, the emergency pump is operated by a ram-air-driven turbine unit. This provides emergency hydraulic power as long as the aircraft is airborne.

14-23. You have seen how the pilot can continue to fly his aircraft safely if a failure develops in his flight control systems. However, he may have another equally serious problem. What if his landing gear fails to operate at the end of his flight? What are the safety provisions for such an event? The next section will tell us.

15. Landing Gear Warning and Emergency Operation

15-1. A landing gear warning system tells the pilot the gear's position during or after a cycle. When the system indicates an unsafe condition, the pilot can resort to emergency operation. We will first discuss the landing gear warning system, then an emergency operation.

15-2. **Landing Gear Warning Sytems.** One type of landing gear warning system uses three green indicating lights for normal or safe conditions. It uses one red light and warning horn for unsafe conditions. One green indicating light for each gear glows when its gear is DOWN and LOCKED. The red warning light glows whenever *any* gear is between the DOWN or UP and LOCKED position. The indicating lights are mounted on or near the pilot's instrumental panel. The red warning light usually is an integral part of the landing gear control knob. A warning horn is used together with the lights to give the pilot an audible warning.

15-3. Now that you are familiar with the units in the warning system, let's see how it works. Let's start with what the pilot sees as he starts to land. After slowing down to where the slipstream will not do structural damage, he can lower the gear. Up to this time, he should not have any warning light indication. He places the landing gear control handle in the DOWN position, and the gear begins to move downward. During this time, the red light glows, indicating that the gear is unsafe. As each gear locks down, its corresponding green light will come on. When all three of the green lights are on, the red light automatically goes off. The pilot then knows it is safe to land.

15-4. During takeoff, all three green lights should be on and the red light off. Shortly after takeoff, the pilot places the landing gear control in the UP position. As the first gear breaks away from its DOWN and LOCKED position, its corresponding green light will go off. The red light now comes on. The red light will not go off until the last gear is up and all the doors are closed. If the red light does not go off, the pilot knows that something is wrong; so, he will probably extend the gear, land the aircraft, and look for the trouble.

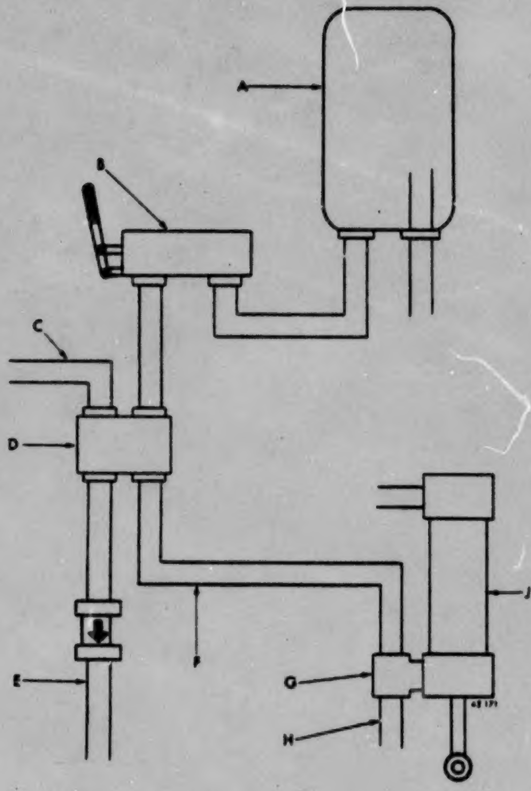
15-5. Another type of warning system used on many of our aircraft is similar to the one just discussed. The main difference is in the landing gear position indicators. The position indicators are electrically operated units which show a picture of the gear position. When any gear is down and locked, a picture of a wheel appears in its indicator window. When any gear is up and locked, the word UP appears in the corresponding window. When any gear is neither locked up nor down, a picture of a barber pole appears in the window. A red warning light is mounted in the landing gear control handle. This light glows when the first wheel well door is opened during extension. It goes off when the last gear goes into DOWN and LOCKED position. During retraction of the gear, the red light glows when the first down lock in unlatched. It will remain on until all gear is up and the wheel well doors are closed. A warning horn is also installed with this system. It warns the pilot, should he forget to lower the gear during landing procedures.

15-6. **Landing Gear Emergency Systems.** As you know, some landing gears depend only on the force of gravity for emergency extension. Others depend on gravity plus hydraulic or air pressure.

15-7. Generally, gravity is used only on those gears whose fall is not hindered by the slipstream. As an example, the gear may retract and extend sideways in relation to the movement of the aircraft. During emergency extension of this type of gear, the uplatches are released by pulling an emergency release. One word of caution about pulling emergency releases, especially during ground testing of the gear: Make sure you are pulling the correct one; otherwise you might drop fuel tanks, or do something else that would be very embarrassing, such as ejecting yourself.

15-8. Gear that extend forward into the slipstream normally use pressure for emergency extension. The hydraulic hand pump system, as shown in figure 61, is one means of providing this pressure. This system can also use hand pump pressure for ground testing the normal system equipment.

15-9. Notice that the hand pump (B) draws fluid from the bottom of the main system reservoir (A). It gets the fluid from there because the emergency may result from a ruptured line in the main system. In this case, the main pump drew out all the fluid above the standpipe. This fluid may have been lost through the broken line. The fluid drawn from the reservoir by the hand pump is pumped to emergency selector valve D. The emergency selector valve has two



A. Reservoir
B. Hand pump
C. Return manifold
D. Emergency selector valve
E. Ground test line to normal system pressure manifold
F. Emergency pressure line
G. Shuttle valve
H. Landing gear subsystem alternating line
J. Actuating cylinder

Figure 61. Hand pump system.

positions: GROUND TEST and EMERGENCY position. When the valve is in the GROUND TEST position, fluid is directed to the normal system pressure manifold line E; at the same time, emergency pressure line F is connected to return manifold C.

15-10. In the EMERGENCY position, fluid is directed to landing gear actuating cylinder J, through emergency pressure line F. This position also connects return manifold line C to normal system pressure manifold line E. Normal system pressure manifold line E is also a part of the normal system pressure manifold. Therefore, a check valve is incorporated in the line. This check valve prevents system pressure from interfering during hand pump operation. This could happen while the emergency selector valve is in the GROUND TEST position. It also prevents loss of pressure through return manifold line C when the valve is in EMERGENCY position.

15-11. Before fluid can enter the actuating cylinder, however, sufficient pressure must be developed to shift shuttle valve G. The purpose of the shuttle valve is to separate the emergency system from normal system H. The shuttle valve permits the use of the normal actuating cylinder for emergency operation of the gear.

15-12. For normal operation, the emergency selector valve is kept in the GROUND TEST position. This allows thermal expansion in the emergency line to be relieved through the return manifold. If it weren't, the thermal expansion of the trapped fluid could reposition the shuttle valve.

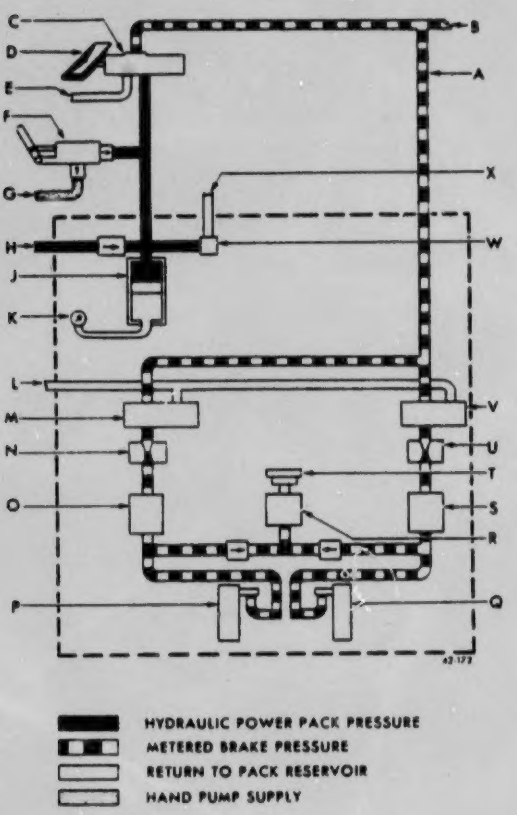
15-13. Our discussion so far has been about flight controls and landing gear. This will allow us to control the aircraft in flight and extend the gear for landing. One more important factor remains—stopping the aircraft after landing. The next section will deal with emergency brakes.

16. Emergency Wheel Brake Systems

16-1. Aircraft need more than one way to operate the wheel brakes. Considerable damage can be done by an aircraft running off the end of the runway to brake failure. Many different types of backup systems are used. Some are referred to as emergency systems and others as auxiliary systems. The method of operation can be by hydraulic pressure or air pressure.

16-2. **Combination Normal and Auxiliary Brake Systems.** Before we get into figure 62, we need some background information. We need to get the picture of the wheel and braking system that we will use as an example. Figure 62 is a part of this system. There are two sets of dual wheels located side by side under the forward part of the fuselage. Two more sets are located side by side toward the rear of the fuselage. The front wheels are called the left forward mains and the right forward mains. The rear wheels are called the left rear and the right rear mains.

16-3. There are four brake systems used, one for each set of dual wheels. The four systems are alike except for the method of metering the fluid to the brakes. The two forward wheel systems use mechanically actuated metering valves. The two rear systems use hydraulically actuated slave metering valves. These receive their pressure signal from one or the other forward metering valves. In order to explain this system systematically, we shall first discuss one of the forward main wheel systems. After this we will see how all four systems are interconnected with each other.



A.	Metered fluid pressure line (to left forward wheels)
B.	Metered fluid pressure line (to rear wheels)
C.	Brake metering valve (left forward)
D.	Brake pedal
E.	Brake metering valve return line
F.	Auxiliary hand pump
G.	Auxiliary hand pump inlet line
H.	Pressure line from power source
J.	Brake system accumulator
K.	Accumulator air pressure gage
L.	Antiskid valve return line
M.	Antiskid valve
N.	Restrictor valve
O.	Hydraulic fuse
P.	Brake unit
Q.	Brake unit
R.	Low-pressure relief valve
S.	Hydraulic fuse
T.	Overboard drain
U.	Restrictor valve
V.	Antiskid valve
W.	Relief valve
X.	Return line

Figure 62. Brake system (left forward main)

16-4. For our first discussion, we will use figure 62. The dotted line in the drawing means this is only part of a larger drawing. Hydraulic pressure enters through pressure inlet line H for the brakes shown in figure 62. It charges accumulator J and pressurizes the line to brake metering valve C. Also installed in this brake system is auxiliary hand pump F. The pump draws its fluid supply from the main system reservoir. It also supplies pressure to the left forward brake metering valve C and to accumulator J. Relief valve W is installed in the system to prevent excessive pressure during hand pump operation. The check valve in pressure inlet H insures that pump F's output goes only to the brake.

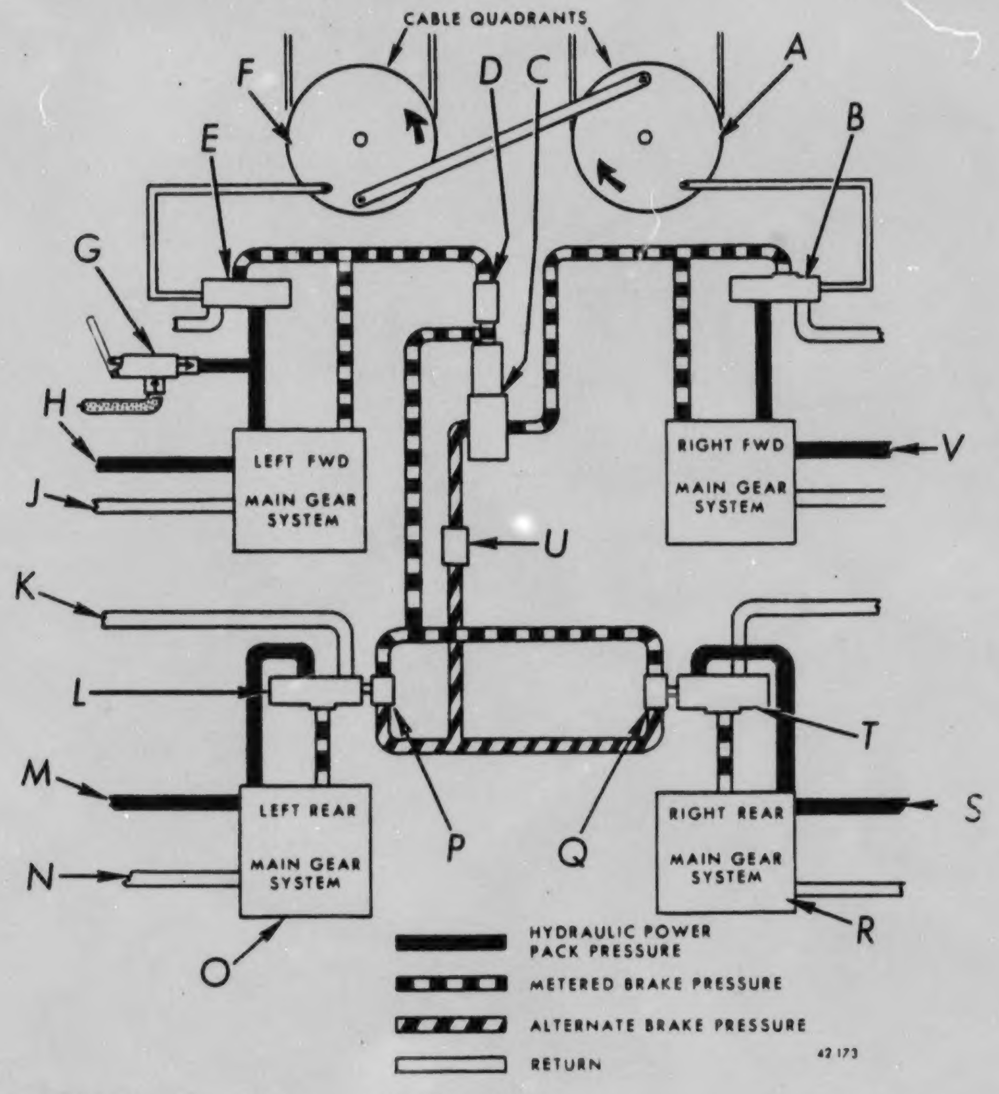
16-5. Air pressure gage K is connected in the pneumatic line of the accumulator. It indicates hand pump and system pressure any time the hydraulic pressure goes above the air preload of an accumulator. Left forward metering valve C delivers metered pressure to the two left forward wheels. Pressure line A goes to the forward brakes and B goes to the aft. The aft brakes are slave operated. Pressure to the brakes is adjusted by the mechanical linkage to the metering valve. Some brake units installed on aircraft do not require pressure in excess of 600 to 800 psi. Therefore, you adjust the linkage so that full system pressure cannot reach the brakes. Consult the aircraft TO for the maximum psi setting. Pressure to the brakes is directly proportional to pedal (D) force applied. To get maximum brake pressure, the pedals must be fully depressed.

16-6. When the pilot applies the brakes, pressure is directed through pressure lines A and B. If you follow pressure line A, you will come to antiskid valves M and V. From the antiskid valves, it is directed through restrictors N and U; then on through hydraulic fuses O and S; and finally to the brake units P and Q. The antiskid system is used on many of our aircraft to prevent wheel skid during braking operation. It automatically releases brake hydraulic pressure from the wheel tending to skid. The solenoid-operated antiskid valves, M and V, are energized and opened by electrically operated skid detectors. These are usually mounted on the hub of the landing gear wheels.

16-7. Restrictor valves N and U are installed in each brake pressure line to dampen out any pressure surges. High pressure surges could damage the brakes or cause unintentional brake locking. Hydraulic fuses O and S are installed in each brake pressure line to limit the loss of hydraulic fluid. Without them, much fluid could be lost by a broken line downstream. Low-pressure relief valve R is installed in the brake line between the hydraulic fuses and the brake units. This valve prevents damage to the brakes from a sudden increase in hydraulic pressure. The brake units are of the hydraulically operated segmented rotor type. Callouts G, L, T, and X are self-explanatory.

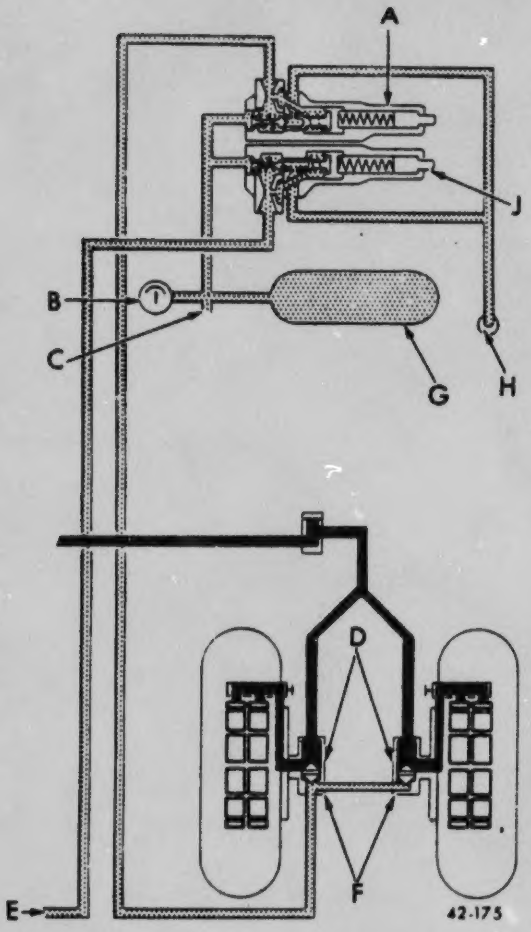
16-8. We have now completed our explanation of the brake system for the left forward main wheels of this aircraft. As previously mentioned, there are four systems installed on this aircraft: one for the left forward wheels and one for the right forward wheels; one for the left rear wheels and one for the right rear wheels. With the exception of the hand pump, the two forward systems are identical. The only difference in the forward and rear systems is the metering valves. The rear systems use slave metering valves, while the front systems use conventional metering valves. In the system are other hydraulic units which are very important in the operation of the brakes. These units are used in the interconnection of the four systems and are shown in figure 63.

16-9. The brake pedal cables in figure 63 are mechanically connected. This is done by the rod which connects cable quadrants A and F. This allows either pedal to position both for-


CABLE QUADRANTS
F
D
C
A
E
B
G
H
V
RIGHT FWD MAIN GEAR SYSTEM
LEFT FWD MAIN GEAR SYSTEM
J
U
K
L
T
M
S
LEFT REAR MAIN GEAR SYSTEM
RIGHT REAR MAIN GEAR SYSTEM
P
Q
N
R
O
HYDRAULIC POWER PACK PRESSURE
METERED BRAKE PRESSURE
ALTERNATE BRAKE PRESSURE
RETURN
42 173

A. Right brake pedal cable quadrant
B. Right forward metering valve
C. Alternate slave control valve
D. Hydraulic fuse
E. Left forward metering valve
F. Left brake pedal cable quadrant
G. Auxiliary hand pump
H. Pressure line
J. Antiskid return line
K. Metering valve return line
L. Slave metering valve
M. Pressure line
N. Antiskid return line
O. Left rear brake system
P. Shuttle valve
Q. Shuttle valve
R. Right rear brake system
S. Pressure line
T. Slave metering valve
U. Hydraulic fuse
V. Pressure line

Figure 63. Complete hydraulic brake system.



A. Right-hand metering valve
B. Air pressure gage
C. Recharging valve
D. Hydraulic pressure points (to shuttle valve)
E. Air pressure line to the left-hand brake assembly
F. Shuttle valves
G. Air bottle
H. Overboard outlet (air brake pressure release)
J. Left-hand metering valve

Figure 64. Air-operated brake system.

ward metering valves. The left forward metering valve provides pressure for normal operation of the aft slave metering valves. The fluid under pressure goes from metering valve E through fuse D. From there, it goes to alternate slave brake control valve C and positions it. Now fluid from the right forward metering valve B *cannot* pass through it. Fluid from the left metering valve also goes on to shuttle valves P and Q. It goes through the shuttle into slave metering valves L and T to operate the brakes. Right forward brake metering valve B furnishes pressure for normal operation of the *right forward brakes only*. Should the *normal system fail*, the right forward metering valve furnishes pressure for the two slave metering valves. This happens when pressure from valve E *cannot hold slave control valve C open*. Then the pressure from metering valve B goes through alternate slave control valve C and through fuse U. It then moves shuttle valves P and Q over to allow fluid from the alternate system to enter slave valves L and T. This insures operation of a minimum of three sets of brakes in either normal or alternate operation. The remainder of the callouts in figure 63 are self-explanatory.

16-10. You may have forgotten the internal operation of some of the units mentioned above. If so, pick up your Volume 2 and refresh your memory of brake components in Chapter 6 of that volume.

16-11. **Air-Actuated Emergency Brakes.** A number of aircraft use compressed air for emergency operation. A typical air-operated brake system is shown in figure 64. The airbrake system consists of air bottle G, gage B, metering valves A and J, and shuttle valves F. The air bottle is equipped with a special quick-disconnect fitting. This enables the bottle to be easily replaced when the air charge is exhausted. The bottle may also be recharged through recharging valve line C. The system is charged to a pressure given in the applicable TO. It is read on gage B located in the pilot's compartment.

16-12. During emergency operation, air pressure is routed through metering valves A and J to the shuttle valves F. Normally, the shuttle valves are held against the air inlet port by internal springs and hydraulic pressure. During airbrake application, the shuttle valves are forced against hydraulic pressure inlet ports D. This prevents air from entering the hydraulic system. Action of air pressure within the brakes is similar to hydraulic fluid application; however, if the brakes are applied by air pressure, you must bleed the brakes of air before further flights. A complete explanation of the bleeding of hydraulic brakes was given in Volume 2, Section 22. Callouts E and H are self-explanatory.

16-13. By understanding the information in this volume, you should be able to adapt it to any aircraft that you work on. The principles of hydraulics and basic system construction remain constant.

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Pneudraulic Systems and Principles of Operation

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ECI Form No. 17

STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume. Use the Guide for review before you take the closed-book Course Examination.

2. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the items missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number

Guide Numbers 300 through 312

300 Introduction to Aircraft Familiarization; Basic Laws of Energy and Matter; Aerodynamics; pages 1–8

301 Aircraft Construction and Identification; Aircraft Types, Distinguishing Characteristics, and Designators; pages 8–13

302 Introduction to Principles of Electricity; Electrical Fundamentals; pages 14–20

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312 Landing Gear Warning and Emergency Operation; Emergency Wheel Brake Systems; pages 61–65

CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

CHAPTER 1

Objectives: To demonstrate knowledge of aircraft recognition and location of components; also, a knowledge of the principles of flight and flight control.

1. What is kinetic energy? Give some examples. (1-5)

2. What are the three states of matter? Give characteristics of each. (1-8–11)

3. In measuring pressure with a manometer, a reading of 5 inches of mercury is equal to what? (2-2)

4. What two factors determine air density? (2-5)

5. What is the effect of high altitude on the maneuverability of aircraft and on the speed of jet aircraft? (2-6)

6. For an aircraft wing to create lift, which must be longer, the upper camber or the lower camber? (2-12)

7. What are the four aerodynamic forces acting upon an aircraft? (2-13)

8. On which surfaces of an aircraft wing are found the higher pressure and the lower pressure during flight? (2-15)

9. Name the three axes around which an aircraft moves. (2-17)

10. What are the terms that describe motion around the three axes of an aircraft? (2-17)

11. About which axis does the elevator rotate the aircraft? (2-20)

12. Which flight controls will a pilot normally use while making a turn? Why? (2-21,22)

13. What functions do elevons serve? (2-26)

14. When the elevator trim tab is moved up, what change in flight attitude will the aircraft make? (2-27)

15. Which control momentarily destroys part of the negative pressure pattern on a wing? (2-31)

16. What type of control assists in maintaining laminar flow across the wing at high angles of attack? (2-35)

17. Which component is the main supporting member of the wing? (3-3)

18. Name the three basic designs of retractable landing gear. (3-4)

19. Give at least two characteristics that enable you to distinguish the following aircraft from each other: B–52G and C–135B; F–104C and F–106A. (4-6–9)

20. Explain the designation of each of the following aircraft: C–9A, RF–4C, B–52G, and KC–135A. (4-10–15)

21. What is used for vertical, lateral, and horizontal reference to locate aircraft components? (4-17–21)

22. What are water lines on an aircraft? (4-20)

23. In what order are aircraft engines numbered? (4-21)

CHAPTER 2

Objectives: To show an understanding of the composition of atoms and the direction of current flow by electron theory; to be able to apply Ohm's law; and to show a knowledge of how to check electrical circuits with the use of a multimeter.

1. What are atoms composed of? (5-2)

2. In electricity, what do we call a substance with a large number of free electrons? (5-3)

3. What type of electrical current is used mostly in pneudraulic circuits? (5-7,8)

4. A battery can be related to which hydraulic unit? Why? (5-9)

5. What is the common term used for electromotive force? (5-11)

6. What causes current to flow in an electrical circuit? (5-11; 7-7)

7. How do you find the total voltage drop in a series circuit that contains several resistive units? (5-14,24)

8. Which direction does current flow under the electron theory concept? (5-16)

9. The current in a circuit is equal to the __________ by the __________. (5-18,19)

10. Name the three types of electrical circuits. (5-23)

11. How do you find the total resistance in a series circuit that contains several resistive units? (5-24)

12. What is the main advantage of using parallel circuits? (5-26,27)

13. How does the total resistance in a parallel circuit compare with the resistance in the individual paths? (5-26)

14. How are units wired into a series-parallel circuit? (5-29)

15. How are aircraft circuits usually wired? (5-31)

16. What determines the strength of the magnetic field in a solenoid? (5-32)

17. Which has the permanent fixed iron core, a relay or a solenoid? (5-32)

18. Define an open circuit. (6-3)

19. How do you find the voltage at a certain point in a circuit? (6-8)

20. What type of electrical trouble would cause a system to operate when the switch for another independent system is closed? (6-11)

21. How would you check to see if a section of wiring is shorted to ground? (6-12)

22. In the above question, what is the reading if there is a short? If there is no short? (6-12,17,19)

23. Give some indications of a grounded circuit. (6-16,17)

24. Give the indications of low-voltage operation of an electric-motor-driven pump. (6-21)

25. What will the AN/PSM–6 VOM measure? (7-2)

26. What is the purpose of adjusting the OHMS ADJ knob prior to using the multimeter? (7-2)

27. Where would one touch the multimeter leads to check the voltage across the coil of a solenoid? (7-4)

28. In a circuit energized by a 24-volt battery, what will be the voltage drop across an open? (7-10)

29. Explain the precautions that should be observed when connecting an ohmmeter to an electrical circuit. (7-13)

30. What kind of a reading will a partial short give on an ohmmeter? (7-14)

CHAPTER 3

Objectives: To demonstrate the ability to describe the operation of hydraulic and pneumatic power systems.

1. What type system has no pressure when its subsystems are not operating? (8-3,4)

2. How are selector valves arranged in an open center system? (8-4)

3. Why is a regulator of some sort required with the use of engine-driven pumps? (8-5,6)

4. Why is an accumulator an important unit in a closed-center system? (8-6)

5. How are the selector valves arranged in a closed-center system? (8-7)

6. Why are line disconnect valves placed on the lines leading to and coming from the power pump? (8-10)

7. What advantage is there in using two power pumps in a hydraulic system? (8-10)

8. Referring to figure 27, what would be the effect on system operation if one of the pumps failed? (8-11; Fig. 27)

9. What hydraulic unit in a closed-center system is not necessary when using a variable-volume pump? (8-12)

10. What is the purpose of controllable check valves in a hydraulic system? (8-13,14)

11. What component regulates the output of the demand type variable volume pump? (8-13)

12. What is the function of a priority relief valve? (8-18)

13. What is the main constructional difference between a balanced priority relief valve and a conventional relief valve? (8-19–21)

14. Should the pressure regulator become inoperative, what unit would prevent excessive pressure in the system? (8-22)

15. In an electrically driven pump power section, how and when does the motor receive current? (8-22)

16. What units usually are the connecting points between pneumatic and hydraulic systems? (9-4)

17. How are the air flasks in the high-pressure pneumatic systems charged? (9-5)

18. What is the primary purpose of the priority valve in the pneumatic system illustrated in figure 31? (9-5; Fig. 31)

19. Why are restrictors check valves placed in the inlet and outlet parts of some pneumatic actuating cylinders? (9-7)

20. Refer to figure 31. After depressurization of the nonpriority air flasks (D) during a ground check, it was determined that the left brake system was inoperative. What would be the most probable cause? (9-9; Fig. 31)

CHAPTER 4

Objectives: To show a knowledge of the construction of actuating cylinders and to explain the operation of different types of actuating systems.

1. In what type actuating system would a nonautomatic control system be used? (10-1)

2. Name three methods of sequencing. (10-3)

3. Why must the operation of some actuating systems be sequenced? (10-3)

4. How is a system sequenced by the pressure method? (10-7)

5. What components are used in electrically sequencing the operation of a hydraulic system? (10-10)

6. When a bomb-bay door opens, why must the jamb latches open before the center latches open? (10-11)

7. In closing the bomb-bay doors, what two things must happen before the jamb latches can operate? (10-11,12)

8. In the electrically sequenced landing gear system shown in figures 39 and 42, are the gear and door control valves moved into or out of neutral by the electrical solenoids? (10-16–18; Figs. 39,42)

9. What provision is made to prevent landing gear retraction while the aircraft is on the ground? (10-18)

10. What is the function of a followup system? (11-1)

11. What type of actuating subsystem would most likely use an automatic position control system? (11-1)

12. What type of followup system uses a set of opposing gears? (11-4)

13. What is the function of hydraulic boost systems? (11-8)

14. What is the purpose of "load feel," and where is it used? (11-8,9)

15. What is the purpose of a control lock system? (12-2)

16. When the control lock system is in the locked condition on the ground, does it prevent all movement of the control surfaces? (12-5)

17. What does the pitch trim system do and to what component? (12-10)

18. How is the pitch trim system actuated? (12-12)

19. Where would a hydraulic slave system be used? (12-16)

20. Give a primary feature of the directional control valve of the rack-and-pinion type steering mechanism. (13-3)

21. What is the reason for opening the bypass valve between the two actuating cylinders of a nosewheel steering mechanism? (13-5)

22. Which unit in the steering damper unit shown in figure 53 would be defective if the steering unit operated while on jacks? (13-9; Fig.53)

23. What would be the most probable cause, in a nosewheel damper system, if the nosewheel would turn in *only* one direction (13-14)

CHAPTER 5

Objective: To demonstrate knowledge of emergency pneudraulic systems and to explain why emergency systems are necessary.

1. What is a basic characteristic of pneudraulic emergency systems in general? (Intro.-1)

2. Do all aircraft have emergency hydraulic systems to use if the normal hydraulic system fails? (14-1)

3. What means can be used to supply emergency pressure? (14-2,22; 15-8; 16-11)

4. Why is the emergency selector valve left in the normal position in the system shown in figure 55? (14-4; Fig. 55)

5. If the normal wing flap extension hydraulic system fails, what is the source of emergency power to extend the flaps? (14-8)

6. How is automatic changeover prevented in the system shown in figure 58 when there is insufficient pressure in the alternate system? (14-14; Fig. 58)

7. In the flight control hydraulic system system shown in figure 59, what is the purpose of pressure switch P? (14-19; Fig. 59)

8. When will the green lights glow in a landing gear warning system? (15-2)

9. What does the red light indicate in a landing gear warning system? (15-2,5)

10. In emergency hydraulic systems, why does the hand pump draw fluid from the bottom of the reservoir while the normal system power pump draws fluid from a stand pipe? (15-9)

11. Is full hydraulic system pressure applied to the aircraft brakes during braking? Why? (16-5,7)

12. What is the source of air pressure for air-actuated emergency braking? (16-11)

13. What maintenance procedure must be performed whenever air has been used for emergency brake application? (16-12)

14. Why are shuttle valves used in hydraulic systems? (15-11; 16-12)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

1. Energy due to motion. Moving car, aircraft in flight, wind, and flowing stream.

2. Solid, liquid, and gas. Solid has definite shape and definite volume. Liquid has definite volume but no definite shape. Gas has no definite volume and no definite shape.

3. It is equal to the weight of 5 inches of mercury.

4. Temperature and pressure.

5. An aircraft is less maneuverable but flies faster for a given thrust.

6. The upper camber must be longer.

7. Lift, weight, thrust, and drag.

8. The higher pressure is on the lower surface and the lower pressure is on the upper surface.

9. The longitudinal axis, lateral axis, and vertical axis.

10. Roll, pitch, and yaw.

11. About the lateral axis

12. Rudder and ailerons. The rudder turns the aircraft and the ailerons are used to bank the aircraft to prevent sideslipping.

13. Both as ailerons and elevators.

14. Tab moves up and forces the elevator down, which raises the tail and lowers the nose of the aircraft (dives).

15. Spoilers.

16. Slots.

17. Spar.

18. Conventional, tricycle, and bicycle.

19. *B-52G*
High wing
Dual engine pods

C-135B
Low wing
Single engine pods

F-104C
Straight wings
"T" tail

F-106A
Delta wings
Squared off stabilizer

20. C–9A - Basic mission cargo, 9th model, 1st series.
RF–4C - Modified mission of reconnaissance, basic mission fighter, 4th model, 3rd series.
B–52G - Bomber, model, 7th series.
KC–135A - Modified to a tanker, basic cargo, model, lst series.

21. Station numbers, buttock lines, and water lines.

22. They are lines which represent horizontal planes in the aircraft which are measured distances from a horizontal reference plane below the aircraft.

23. Numbered from left to right.

CHAPTER 2

1. Electrons (negatively charged particles), protons (positively charged particles), and neutrons (neutral particles).

2. A conductor; in general, metals and their alloys.

3. Direct current.

4. An accumulator. The battery stores electrical energy (pressure), whereas the accomulator stores hydraulic pressure.

5. Voltage.

6. Current will flow any time there is a difference in voltage between two points.

7. You add the voltage drops of all the units *or* you read the voltage of the power source.

8. Negative to positive.

9. Voltage divided; resistance.

10. Series, parallel, and series-parallel.

11. You add the resistances of all the units.

12. In a parallel circuit, when one unit burns out the other will still operate. In a series circuit, when one unit burns out the others will not operate.

13. The total resistance of the entire circuit is less than the smallest resistance of any path.

14. Some units are in the series part of the circuit and others are wired into parallel portions.

15. Aircraft circuits are usually one wire circuits with the airframe acting as ground.

16. The strength of the magnetic field depends upon the number of turns of wire in the coil and the amount of current passing through it.

17. The relay.

18. An incomplete circuit caused by an accidental break in the wire is called an open circuit. Any time we have an incomplete circuit, we have an "open" circuit.

19. Place the positive lead of a voltmeter at the point and the ground lead on the aircraft structure.

20. A short circuit, "short," or "shortened circuits." A short can be caused by two wires rubbing together and breaking down the insulation.

21. Disconnect both ends of the wire and place one ohmmeter lead on the wire and the other on the aircraft structure.

22. The reading is a low resitance if there is a short and an infinity resistance if there is no short.

23. When a positive lead is grounded, there will be little or no resistance, which will cause very large currents to flow. Voltage will decrease to zero. Wires will heat up because of the current flow, with a possibility of fire.

24. Low voltage would cause the motor to run slowly and also cause overheating.

25. The AN/PSM–6 is used to measure volts, amperes, and ohms.

26. To zero the pointer on the ohms scale, which will compensate for a decrease in battery voltage due to age and use.

27. At each terminal of the coil.

28. 24 volts.

29. When an ohmmeter is used, the component under test must be disconnected from the circuit or the electrical power must be turned off.

30. Somewhere between an infinity and a zero ohms reading.

CHAPTER 3

1. Open-center system.

2. In series with each other.

3. A constant load on the pump would wear it out quickly. The regulator takes the load off the pump except at times of peak loads.

4. It stores fluid under pressure for faster and smoother system operation and prevents the regulator from operationg too frequently through minor system leakage.

5. In parallel to each other.

6. To aid in the removal of the pump without excessive loss of fluid, and for test stand connection.

7. A more steady and rapid flow of fluid; also, if one of the pumps should fail, the remaining pump keeps the system in operation.

8. System would operate, but at a slower rate, and a check valve prevents motorizing the dead pump.

9. Pressure regulator.

10. They can be closed to isolate various sections.

11. The pump compensator.

12. It insures minimum pressure at all times in some part of the hydraulic system, whether or not other parts of this system are in operation.

13. A balanced priority relief valve has a rod attached to the ball on the back side to eliminate back pressure effect, whereas a conventional relief valve does not.

14. System relief valve.

15. After the start switch is closed, the motor gets power whenever the system pressure switch closes (because of lowered pressure).

16. Shuttle valves.

17. Either from a high-pressure air compressor or from a nitrogen cart.

18. To reserve air pressure for operating the ram-air turbine, drag chute, speed brakes, and landing gear in the event air pressure in the nonpriority flasks drops below a given point.

19. For snubbing action and speed control.

20. The leaking check valve (K).

CHAPTER 4

1. In systems where full-throw operation is necessary.

2. Mechanical, electrical, and pressure.

3. To prevent some part of the system from interfering with the operation of other parts of the system.

4. By relief valves with successively higher settings.

5. Motor or solenoid controlled valves and microswitches.

6. If the center latches were opened first, the doors would partly open and bind the jamb latches.

7. The doors must close and the center latches must be latched before the jamb latches can operate.

8. The gear and door control valves are moved out of neutral by electrical solenoids and into neutral by hydraulic pressure.

9. A ground safety switch on the gear breaks and gear-up circuit while the aircraft is on the ground.

10. It returns the selector valve to the neutral position when the desired travel has been reached.

11. Control surface boost and nosewheel steering systems.

12. Differential type.

13. To facilitate pilot control of the flight controls.

14. It helps prevent overcontrol by giving the pilot an indication of the force necessary to move the controls. It is used in control surface boost systems.

15. Prevents damage due to fluttering of control surfaces while the aircraft is on the ground.

16. No, they can be moved slowly.

17. It raises or lowers the front edge of the horizontal stabilizer to change its angle of attack. Thereby, it corrects for a nose high or low attitude.

18. By two independent actuators. One is electrical and the other is hydraulic.

19. On large aircraft to operate isolated mechanisms, thereby saving weight in tubing, fittings, and fluid.

20. A primary feature is an open-center type valve.

21. To let the nosewheel swivel freely during towing.

22. A broken spring in the safety shutoff valve (E).

23. A clogged orifice check valve.

CHAPTER 5

1. They operate only those compoents essential for mission completion and safety; also, they differ on every aircraft.

2. No, some require manual override by the pilot.

3. Hand pumps, ram-air turbine, electrically driven pumps, and air stored under pressure.

4. To prevent fluid expansion, due to temperature rise, from shifting the shuttle valves.

5. An electrically driven hydraulic pump and an emergency reservoir.

6. By using the alternate system pressure switch (K) as a ground for the alternate system shutoff valve (L) and the normal system bypass valve (B), there will not be a complete circuit.

7. To allow changeover to the alternate system only if it is pressurized sufficiently.

8. When each gear is down and locked, its green light will glow.

9. An unsafe condition in the landing gear system during extension or retraction.

10. In case there is a ruptured line the power pump cannot pump all the fluid in the reservoir overboard. The fluid below the standpipe inlet is reserved for emergency use, pressurized by hand pump.

11. No, full system pressure would damage the brakes.

12. Compressed air bottles.

13. The mechanic must "bleed" the brakes before the next flight.

14. To separate emergency systems from normal systems.

STOP– **1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.** **2. USE NUMBER 1 PENCIL.**

42152 03 25

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: TEXT PAGE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Text Page Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Text Pages* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to the VRE booklet and locate the *Text Page Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

Multiple Choice

Chapter 1

1. (001) The law of the conservation of energy states that energy can be

a. created only.	c. either created or destroyed.
b. destroyed only.	d. neither created nor destroyed.

2. (002) Matter having definite shape and a definite volume should be classified as a

a. solid.	c. gas.
b. liquid.	d. semiliquid.

3. (002) Matter in the liquid state has

a. a definite shape and volume.
b. no definite shape or volume.
c. a definite volume but no definite shape.
d. no definite volume but a definite shape.

4. (002) A fixed volume of gas will exert a greater pressure when it is

a. cooled.	c. compressed.
b. heated.	d. subjected to moisture.

5. (003) The *maximum* amount of water vapor that the air can hold depends primarily on what characteristic of the air?

a. Density.	c. Composition.
b. Altitude.	d. Temperature.

6. (003) The reference line which runs straight through the airfoil and connects the farthermost points of the leading and trailing edges of the airfoil is the

a. chord.	c. lateral axis.
b. camber.	d. vertical axis.

7. (003) If the lift of an aircraft is equivalent to its weight, theoretically, the aircraft should

a. climb slowly.	c. fly erratically.
b. descend slowly.	d. maintain a constant altitude.

8. (004–005) The motion of an aircraft about the longitudinal axis is called

a. yaw.	c. roll.
b. lift.	d. pitch.

9. (005) The flight control surfaces that control the movement of an aircraft about the lateral axis are the

a. slots.	c. ailerons.
b. rudders.	d. elevators.

10. (006) The flight control surfaces that serve as two separate flight controls are the

    a. elevons.
    b. trim tabs
    c. wing flaps.
    d. stabilators.

11. (007) The flight control surfaces that are designed to compensate for load changes are the

    a. spoilers.
    d. trim tabs.
    c. fixed tabs.
    d. movable stabilizers.

12. (008) The aircraft slots are located on the

    a. leading edge of the wing.
    b. trailing edge of the wing.
    c. training edge of the elevator.
    d. trailing edge of the ailerons.

13. (008) The main support members running fore and aft of the aircraft fuselage are called

    a. formers.
    b. stringers.
    c. longerons.
    d. bulkheads.

14. (008–009) The main support members for the wings of an aircraft are the

    a. ribs.
    c. spars.
    c. formers.
    d. longerons.

15. (009–010) The wing dihedral is a distinguishing characteristic of an aircraft that describes the

    a. sweepback of the wing.
    b. up or down slant of a wing.
    c. position of the wing is mounted in the fuselage.
    d. ratio of the thickness of the wing to the cross-sectional area.

16. (009–011) When making a distinction between the different aircraft existing within a type, the aircraft identifying designator that should be listed first is the

    a. basic mission symbol.
    b. status suffix symbol.
    c. aircraft series symbol.
    d. modified mission symbol.

17. (011) In the system of designation for all Department of Defense aircraft, an S mission symbol designates that an aircraft is of what type?

    a. Research.
    b. Search/Rescue.
    c. Antisubmarine.
    d. Special electronic installation.

18. (013) When locating specific aircraft units, aircraft station numbers are used to represent the distance from station 0 in

    a. inches.
    b. feet.
    c. yards.
    d. meters.

19. (014) Due to the small proportion of free electrons they contain, what substances may be used as insulators?

a. Mica, silver, and rubber.
b. Mica, rubber, and copper.
c. Copper, bakelite, and glass.
d. Mica, bakelite, and plastics.

20. (016) When referring to an ac electrical circuit, a hertz is

a. ½ cycle per second.
b. 1 cycle per second.
c. 1½ cycles per second.
d. 2 cycles per second.

21. (016) Which unit in the aircraft hydraulic system serves the same function as a battery in an electrical system?

a. Accumulator.
b. Relief valve.
c. Control valve.
d. Actuating unit.

22. (016) The pressure that forces free electrons through a conductor is called the electromotive force or the

a. wattage.
b. amperage.
c. voltage.
d. resistance.

23. (016) An electrical current consists of electrons moving through a closed circuit from

a. positive to negative.
b. negative to positive.
c. positive to positive.
d. negative to negative.

24. (017) According to Ohm's law, the current in an electrical circuit that has a resistance of 12 ohms and a power supply of 48 volts would be

a. 2 amperes.
b. 4 amperes.
c. 24 amperes.
d. 96 amperes.

25. (017) In a series circuit, the total resistance will be

a. less than the largest resistor in the circuit.
b. the total of all the resistors in the circuit.
c. less than the smallest resistor in the circuit.
d. equal to the total current divided by the total voltage.

26. (018) An advantage of a parallel circuit over a series circuit is that

a. the parallel circuit operates at a lower voltage than the series circuit.
b. the parallel circuit does not require as much current as the series circuit.
c. the parallel circuit provides an independent path for two or more electrical devices to operate.
d. if one device fails, the remaining portion of the parallel circuit will not operate.

27. (018) The total current in a parallel circuit is

   a. equal to the product of the current flowing through all branches of the circuit.
   b. equal to the current flowing through the largest branch of the circuit.
   c. equal to the sum of the current flowing through all the branches of the circuit.
   d. less than the smallest current through any branch of the circuit.

28. (020) In aircraft wiring installations were connections from each piece of equipment are made directly to the structure of the aircraft, the metallic parts of the aircraft structure serve as

   a. ground.
   b. insulators.
   c. power leads.
   d. the parent circuit.

29. (020) An open circuit is an electrical circuit in which

   a. the path is broken.
   b. an additional device is placed in the system.
   c. the current flow is too high for voltage input.
   d. the voltage is not enough to overcome the current load.

30. (021) If a lamp won't light although a voltmeter indicates that there are 24 volts of power in the lamp and 24 volts at the other side of the lamp, the most probable cause is that

   a. the lamp is burned out.
   b. a short occurred before the light.
   c. an open occurred before the light.
   d. an open occurred in the ground wire.

31. (022) When a short develops in an electrical lead, circuit resistance

   a. increases.
   b. decreases.
   c. fluctuates.
   d. stops all current flow.

32. (023) In a grounded circuit, there will be a

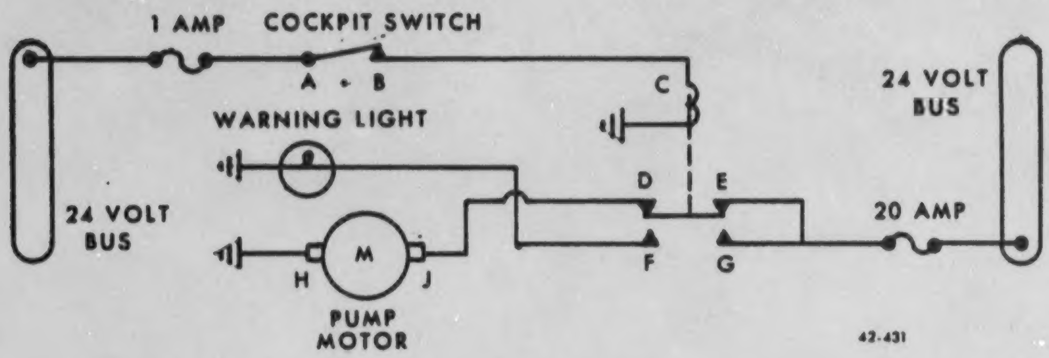
   a. higher voltage flow through the circuit.
   b. a higher current flow because of lower resistance.
   c. higher current flow because of higher resistance.
   d. greater number of ohms in each unit or device.

33. (026) Refer to figure 23 of the text. When a multimeter is used to measure the voltage drop across a 24-volt dc operated pump motor, the

   a. reading is taken on the 0–5 dc scale.
   b. reading is taken on the 0–50 dc scale.
   c. FUNCTION switch is set on D.C.V. and the RANGE switch is set on 24.
   d. FUNCTION switch is set on either 1000 ohms-per-volt or 20,000 ohms-per-volt.

34. (026) Refer to VRE Figure 1. Assume that the warning light goes off when the cockpit switch is closed, but the pump motor does not operate. If a voltmeter reads 24 volts when connected between pin D and ground, pin J and ground, and pin H and ground, you know that the

a. 20-ampere fuse is blown.
b. motor ground lead is open.
c. relay points are defective.
d. motor is internally shorted.



Volume Review Exercise Figure 1

35. (027) If there is an open lead in a circuit being checked for continuity, the ohmmeter will

a. not indicate.
b. indicate 0 ohms.
c. indicate infinity.
d. indicate below normal.

36. (027) If a relay is shorted out against the component housing, the reading on an ohmmeter would indicate

a. infinity.
b. low resistance.
c. high resistance.
d. no change in resistance.

Chapter 3

37. (028) The maximum pressure buildup in an open-center system is limited by the

a. pump compensator.
b. pressure regulator.
c. system relief valve.
d. open-center selector valve.

38. (030) The advantage of a closed-center system over an open-center system is that the closed-center system can

a. only be used on old type aircraft.
b. operate only one subsystem at a time.
c. operate two or more subsystems at a time.
d. keep the power pump unloaded at all times.

39. (030) The unit used in a hydraulic system that equally divides the fluid between two units or systems is a

a. shuttle valve.
b. priority valve.
c. flow equalizer.
d. constant flow valve.

40. (030–031) The use of two power pumps in a closed-center system results in

a. more even fluid flow.
b. greater possible pressure.
c. faster operation of all mechanisms.
d. the continuation of one pump to produce if the other pump fails.

41. (031) When one of the dual pumps in a closed-center system fails, the unit that prevents the good pump from motorizing the failed pump is a

a. foot valve.
b. check valve.
c. shutoff valve.
d. compensator piston.

42. (031–032) In closed-center systems, as system pressure increases, the variable-volume pump

a. output decreases.
b. output increases.
c. output remains the same.
d. input drops to zero.

43. (032) What unit in a hydraulic system is *not* necessary when using a variable-volume pump?

a. Reservoir.
b. Relief valve.
c. Selector valve.
d. Pressure regulator.

44. (032) The unit used to isolate various parts of the hydraulic system is a

a. relief valve.
b. control valve.
c. priority valve.
d. controllable check valve.

45. (033) A balanced-type relief valve can

a. not be used as a system relief valve.
b. not eliminate back pressure in the hydraulic system without changing pressure in the system.
c. give priority of operation to a particular subsystem.
d. unload the engine-driven pump when the systems are not being operated.

46. (036) An aircraft pneumatic system is *serviced* by

a. an engine compressor.
b. cabin pressurization.
c. a ground air compressor.
d. a pneumatic pump on the engine.

47. (033–036) Aircraft peneumatic systems are primarily used as

a. normal systems.
b. emergency systems.
c. landing gear systems.
d. flight control systems.

48. (036–037) The drag brace accumulator pressure is used for

a. brake operation.
b. regulating the rudder feel cylinder.
c. lowering the landing gear in an emergency.
d. starting the engine when an air cart is not available.

Chapter 4

49. (038) The selector valve in a nonautomatic hydraulic actuating system is controlled

a. by microswitches.
b. manually by the operator.
c. by electrical sequencing.
d. by mechanical sequencing.

50. (038) When the operation of various system units of a hydraulic actuating system must occur in proper sequence, the control of the sequencing system is *not* applied

a. manually.
b. hydraulically.
c. electrically.
d. mechanically.

51. (039) In a pressure type sequencing, the type of valve that is used to set up the sequencing operation is a

a. relief valve.
b. pressure reducer.
c. pressure regulator.
d. pressure control valve.

52. (040) A system that commonly uses electrical sequencing is the one that operates the

a. flaps
b. ailerons.
c. pitch trim.
d. cargo doors.

53. (041) Some aircraft landing gear systems have a COMBAT position on the control lever to

a. insure that the landing gear stays retracted.
b. reduce the number of pressurized hydraulic lines.
c. keep pressure in the hydraulic lines for fast extension.
d. keep pressure off the hydraulic lines so that the gear can free fall in an emergency.

54. (041) The safety feature used on a landing gear system that prevents accidental gear retraction on the ground is

a. a gear handle safety pin.
b. that the warning horn and light will come on when the gear is up.
c. that the main gear safety switch breaks contact in the gear up circuit when the weight of the aircraft is on the landing gear.
d. that the steering valve must be deenergized before the gear handle can be placed in either position.

55. (042–043) Hydraulic actuating systems that may incorporate "load feel" are

a. landing gear and brake systems.
b. control surface boost and brake systems.
c. wing flaps and nosewheel steering systems.
d. control surface boost and landing gear systems.

56. (043–044) When an automatic position control system is incorporated into an acutating system, the control system will

a. require followup.
b. require load feel.
c. not require followup.
d. not require load feel.

57. (043–044) The two most widely used followup mechanisms used on aircraft automatic position control systems are the

a. mechanical type and the manual type.
b. mechanical type and the electrical type.
c. mechanical type and the differential type.
d. differential type and the electrical type.

58. (046–047) With a differnetial followup system, the followup action will catch up and neutralize the selector valve when

a. mechanical input stops.
b. electrical input stops.
c. the actuators are at their extremes.
d. a countermechanical movement is exerted.

59. (047) In a closed-center boost system, the pilot gets load feel from

a. the reaction chamber pressure.
b. air preload pressure in the boost cylinder.
c. a reaction to the pneumatic pressure applied.
d. the mechanical linkage and by doing part of the work or moving the control surface.

60. (048) The purpose of the control lock system is to

a. prevent the linkage from moving during maintenance.
b. insure that surfaces are properly aligned for takeoff.
c. prevent control column movement during cable adjustments.
d. prevent fluttering of the control surfaces by gusts of wind on the ground.

61. (050) The control surface on which the pitch trim system is located is the

a. rudder.
b. aileron.
c. elevator.
d. horizontal stabilizer.

62. (050) When fine adjustment of the pitch trim system is desired, the system is operated

a. manually.
b. mechanically.
c. electrically.
d. hydraulically.

63. (050) An advantage of a hydraulically operated slave system on aircraft is that it

a. reduces weight.
b. gives faster operation of the primary system.
c. reduces the mechanical advantage gained by the linkage.
d. will allow the slave system to operate should the primary system fail.

64. (051) A characteristic of some aircraft steering mechanisms which does *not* describe nosewheel steering on aircraft is that it

a. reduces wear on tires.
b. reduces taxiing speeds.
c. requires the pilot to use the brakes more.
d. requires less attention on the part of the pilot.

65. (052) A bypass valve controlled either mechanically or electrically is installed in some nosewheel steering systems to

a. allow the aircraft to be towed.
b. override steering control inflight.
c. bypass the filter if it becomes clogged.
d. allow pressure to go directly to the steering cylinders.

66. (053) The followup mechanism is used with nosewheel steering to

a. give the pilot "load feel."
b. permit the aircraft to be towed.
c. keep the nosewheel in the desired position.
d. return the nosewheel to the straight-forward position.

Chapter 5

67. (055) In an electrically operated emergency system, the pressure-limiting device is a pressure

a. switch.
b. regulator.
c. relief valve.
d. reducing valve.

68. (055–056) The emergency selector valve in an emergency hydraulic system is set in the NORMAL position to prevent

a. draining of the main reservoir.
b. fluid expansion from shifting the shuttle valves.
c. damage to the actuators due to thermal expansion.
d. accidentally unlocking the landing gear while on the ground.

69. (057) Refer to figure 56 of the text. Check valve N installed in the pressure line will insure that pressure during

a. normal operation will not get into the control valve.
b. emergency operation will not escape into the normal system.
c. normal operation will not escape into the emergency system.
d. emergency operation will not get into the hydraulic motor.

70. (057–058) Refer to figure 58 of the text. If the normal system fails, the pressure switch that the changeover to the alternate system cannot be made unless there is ample pressure in the alternate system is pressure switch

a. C.
b. L.
c. H.
d. K.

71. (061) On a landing gear warning system, the red warning light in the landing gear control handle glows when the gear

a. is UP and LOCKED.
b. is DOWN and LOCKED.
c. should be put into DOWN.
d. is between DOWN and LOCKED.

72. (061) Emergency extension of landing gears that extend into the slipstream is accomplished by using

a. a handcrank.
b. air pressure.
c. the force of gravity.
d. hydraulic pressure.

73. (062) In landing gear emergency systems, shuttle valves are installed in the hydraulic system to allow the

a. emergency reservoir to supply the normal system.
b. normal reservoir to supply the emergency system.
c. emergency actuating cylinders to function during ground test.
d. normal actuating cylinders to function during emergency operation.

74. (062) Aircraft emergency brakes may be operated by

a. air pressure or electricity.
b. hydraulic pressure or electricity.
c. air pressure or mechanical linkage.
d. hydraulic pressure or air pressure.

75. (063) When hydraulic pressure goes above air preload pressure, the air pressure gage on an emergency brake accumulator will indicate

a. only preload pressure.
b. only hand pump pressure.
c. only system pressure.
d. hand pump and system pressure.

2-4

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CDC 42152

AIRCRAFT PNEUDRAULIC REPAIRMAN

(AFSC 42152)

Volume 4

Ground Equipment, Schematics, and Supervision and Training

Extension Course Institute

Air University

PREFACE

THIS FOURTH and final volume of Course 42152, *Aircraft Pneudraulic Repairman*, contains three chapters. The first chapter covers shop and aerospace ground equipment and discusses test stands, jacks, maintenance stands, portable compressors, and ultrasonic cleaners. The second chapter covers the use of hydraulic schematics on different types of systems. Chapter 3 finalizes the course with the coverage on supervision and training. Here you learn about manning, supervisory responsibilities and training.

Code numbers appearing on figures are for preparing agency identification only.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TTOC), Chanute AFB, IL 61868.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 15 hours (5points).

Material in this volume is technically accurate, adequate, and current as of November 1971.

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2 USE OF HYDRAULIC SCHEMATICS 31

3 SUPERVISION AND TRAINING 41

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CHAPTER 1

Shop and Aerospace Ground Equipment

THE PNEUDRAULIC repairman performs maintenance which requires the use of shop and aerospace ground equipment. His duties in the pneudraulic shop, for example, are to repair hydraulic components. Before a component is repaired, it must be cleaned. After it is repaired, it must be tested. The test will tell us if it is working correctly or if it needs further adjustment.

2. In order to perform these tests, the shop must be equipped with the proper test stands and testing devices. The equipment authorized for a shop varies and usually depends on the level of maintenance to be done in the shop. If maintenance consists of only removal and replacement of parts, little special test equipment is needed. Where units are completely overhauled, complex machines made to service test the units are needed.

3. There are also a number of portable test stands used by the hydraulic mechanic. He uses them to pressurize and fill aircraft hydraulic systems. Air compressors are required to pressurize both high- and low-pressure pneumatic systems and units.

4. Other equipment you will often use is jacks and maintenance stands. Sometimes you may even have to help repair them. Jacks are used mainly to raise aircraft for working on landing gear and wheels or for making retraction tests. Maintenance stands have hydraulic elevating gear to raise them. They are used by maintenance men when working on aircraft sections they cannot reach from the ground.

5. The pneudraulic mechanic's use of ultrasonic cleaners for cleaning wire mesh filters has become standard. He also uses a hose and fitting assembly machine to make up his hydraulic hoses.

6. To perform the duties of your specialty you will use many kinds of shop and aerospace ground equipment. Naturally, you must know how they work. You must know how to use them correctly, and you must know how to maintain them. This chapter will give you some of the knowledge you need for these duties.

1. HCT-6 Hydraulic Component Tester

1-1. An overall view of the HCT-6 is shown in figure 1. This nonportable hydraulic test stand is standard equipment in most pneudraulic shops. The stand has five hydraulic testing circuits to provide either dynamic or static test of components. The limits on what can be tested are determined by the range of the tester system being used. Some examples of components that can be tested are actuating cylinders, hand pumps, power pumps, and relief valves. The appropriate technical order indicates the type of test required. The hydraulic systems of the HCT-6 supply fluid at controlled temperature, pressure, and flow rates to the outlets. The power supply and control components will be covered in the system which they serve.

1-2. Figure 2 is a block diagram showing the relationship between the main test circuits. The reservoir is shown as supplying fluid to the five hydraulic test circuits.

1-3. **Internal High-Pressure Pump Circuit.** This circuit consists of the usual supply power source and regulating systems found in any other hydraulic system. It supplies hydraulic fluid at controlled pressures and rates of flow. It is sent to the component and actuating test circuits for static and dynamic testing of hydraulic units.

1-4. *Suction supply circuit.* The suction supply circuit provides the necessary fluid to the five test circuits as shown in figure 2. This circuit stores hydraulic fluid in the reservoir (1), shown in the left-hand center portion of figure 3. (See nomenclature in fig. 4.) A reservoir fluid level sight gage (3) is located on the front of the reservoir. The reservoir is also equipped with heaters that will hold the fluid temperature between 70°F. and 170°F. You set the reservoir heater control switch (94) to the temperature setting you want. The temperature will be

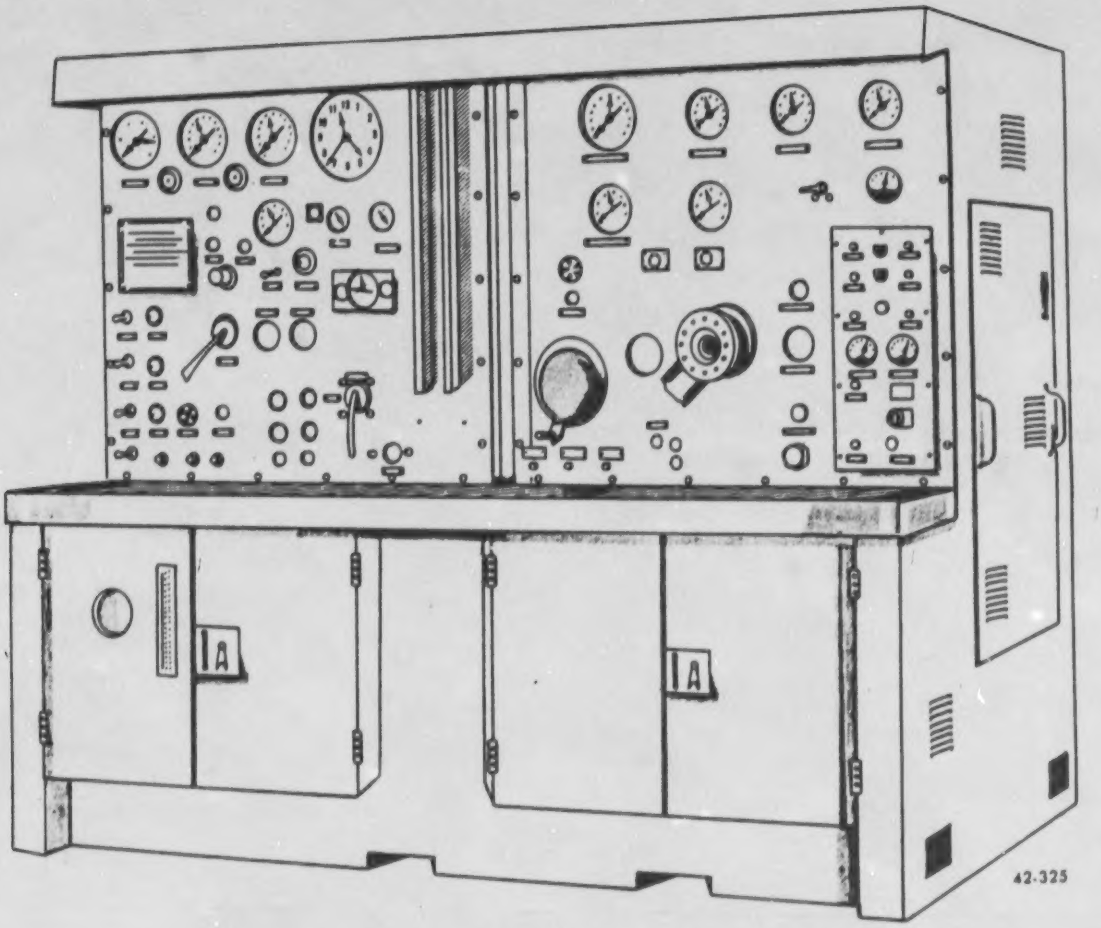

Figure 1. HCT-6 hydraulic component test stand.

shown on the temperature gage (95). These heaters raise the temperature from 60°F. to 100°F. in 15 minutes with 25 gallons of fluid in the reservoir. A time compliance technical order caused a reservoir level switch (110) to be installed in the reservoir. This switch turns off the heaters if the fluid drops below the 3/4 level. A reservoir heater switch (111) on the control panel allows for manual operation of the heaters. The reservoir has a rated capacity of 25 gallons of fluid and can be pressurized from 0 to 125 psi.

1-5. The reservoir receives its air pressure from an external shop source. Pressurization from the air pressure circuit is held between 3 and 125 psi by the air pressure regulator (90). A reservoir pressure selector valve (92) allows the operator either to pressurize or vent the reservoir to the atmosphere. The pressure within the reservoir is indicated on the 0- to 160-psi reservoir pressure gage (91). The gage is equipped with a gage shutoff valve (91A) and a test port (91B). The relief valve (93) installed in the pressure line is set at 125 psi. It prevents the pressure from exceeding the rated working pressure of the reservoir.

1-6. Fluid from the reservoir (1) passes through a shutoff valve (5) and a suction line filter (6) where foreign particles are removed. The filter relief valve (18) is set at 50 psi. The filter element is bypassed by the fluid in the event it becomes clogged. The schematic shows the bypass valve as being a separate unit; however, it is an integral part of the filter housing. The filter pressure switch (7) will light a lamp on the panel whenever the filter becomes clogged. This switch is not factory set and is to be adjusted in accordance with base SOPs. The air bleed valve (17) is installed at the highest point in the suction circuit to vent it of air. The low suction pressure switch (8) stops the pump motor whenever a vacuum develops

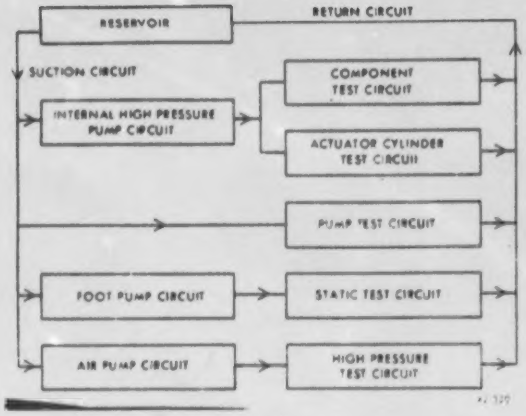

Figure 2. Main test circuits.

in the suction circuit. It is set to open when the pressure drops to 7 inches of Hg (mercury).

1-7. *Power pressure circuit.* The first unit in this circuit is the variable-volume, pressure-compensated, piston-type pump (9). It is driven by an electric motor rated at 30 hp, but can develop up to 50 hp. This pump has a rated capacity of 15 gpm at 3000 psi or 10 gpm at 5000 psi. Fluid is drawn from the reservoir and delivered under pressure to the pressure manifold. A volume control (10) and a pressure compensator (11) permit setting the pump to meet testing requirements. The check valve (12) installed downstream of the pump prevents excessive back pressures from hurting the pump. After flow passes the check valve, the fluid is directed to the test stand relief valve(13). This valve can be adjusted from 500 to 5000 psi to limit maximum system operating pressure. The valve should be adjusted from 200 to 400 psi higher than maximum test pressure. Never adjust below 500 psi, as damage to its seals may result. The solenoid-operated bypass valve (14) is installed in the system so that it can be depressurized. This is done by moving a toggle switch on the control panel. This valve is also operated by the pressure switch (72) that is installed in the pump test circuit.

1-8. **Component Test Circuit.** This circuit is schematically shown in the center right-hand portion of figure 3. Basically, it consists of a pressure manifold and two return lines. Incorporated in the pressure manifold is a 0- to 6000-psi test pressure gage (19). It records the system pressure for both the component and cylinder test circuits. The gage shutoff valve (19A) isolates the gage from the hydraulic system during calibration and service. The test port (19B) allows the gage to be calibrated without removing it from the stand. (Every gage on this stand is equipped with a shutoff valve and test port; all shutoff valves are kept in the OPEN position during normal operation.) Downstream of the pressure gage is a 200-cubic-inch accumulator (20). This unit absorbs pressure surges and pump pulsations. The accumulator shutoff valve (21) is used to isolate the accumulator from the circuit. A check valve (108) is installed downstream of the sensing element in the flowmeter outlet line. This is to prevent damage to the flowmeter when the solenoid bypass valve (14) is operated. The accumulator (20) should be charged with nitrogen to 1500 psi through the accumlator charging circuit. It consists of a charging valve (23), pressure gage (22), gage shutoff valve (22A), and the gage test port (22B). From the accumulator the fluid under pressure is directed to the component test circuit outlets (25 or 27) through their respective shutoff valves (24 and 26). These valves are pressure-balanced spool-type units. This allows them to be operated against 3000 psi as easily as against 0 psi. Flow through the component test circuit return inlets (28 or 30) is controlled by their respective return shutoff valves (29 and 31). You will notice in the schematic that return inlet (30) sends the return flow through the flowmeter (33). If it is unnecessary to measure the return flow, use return inlet (28). It is connected directly to the reservior (1) and bypasses the flowmeter (33). Because the return circuit is a complex circuit in itself, it will be covered separately later.

1-9. **Cylinder Test Circuit.** This circuit is also pressurized by the internal high-pressure pump circuit. Opening the shutoff valve (37) shown in figure 3 directs fluid to the open center selector valve (38). It, in turn, directs fluid to the CYL 1 position outlet (39) or to the CYL 2 position outlet (40). Note: When using the cylinder circuit selector valve (38), close the shutoff valve (37) before changing the position of the selector valve. The third position, FLOWMETER RETURN, is the neutral position of this open center selector valve (38). This position connects the internal high-pressure pump circuit to the flowmeters (33) in the return circuit. The FLOWMETER RETURN position, in turn, blocks the CYL 1 and CYL 2 outlets (39 and 40). The selector valve must be in this position when you adjust the volume output of the stand. A check valve (12) is installed in the return line downstream of the selector valve to prevent a reverse flow.

1-10. **Pump Test Circuit.** This circuit is used to test engine driven pumps. The pump test circuit is schematically shown in the lower right-hand portion of figure 3. The pump suction port is connected to the appropriate outlet (64). Fluid supply to the pump is controlled by a pump test inlet pressure regulator (62). This is a pilot-operated relief-valve type of pressure regulator. The pump test inlet pressure regulator will maintain the set pressure as speed and flow are varied. This prevents damage to the pump under test by either high or low supply pressure.

1-11. A suction flow indicator (63) gives the operator a visual indication of flow to the pump inlet. The pressure port of the pump is connected to the pump test pressure return inlet (70). The pump output pressure is indicated on the 0- to 6000-psi gage (71). As the pressure in the pump test circuit return line rises above 125 psi, the pressure switch (72) closes. The switch energizes the bypass valve (14) to the OPEN position. This causes the fluid that is being pumped by the internal high-pressure pump (9) to be bypassed into the return circuit. Thereby, a minimum of power is required for turning the pump. Keep in mind that the high-pressure pump (9) is driven by the same electric motor that drives the pump test pad. However, this reduction in power is necessary only when the pump test pad is rotated in a counterclockwise direction. This is also the normal direction of rotation of the internal high-pressure pump (9).

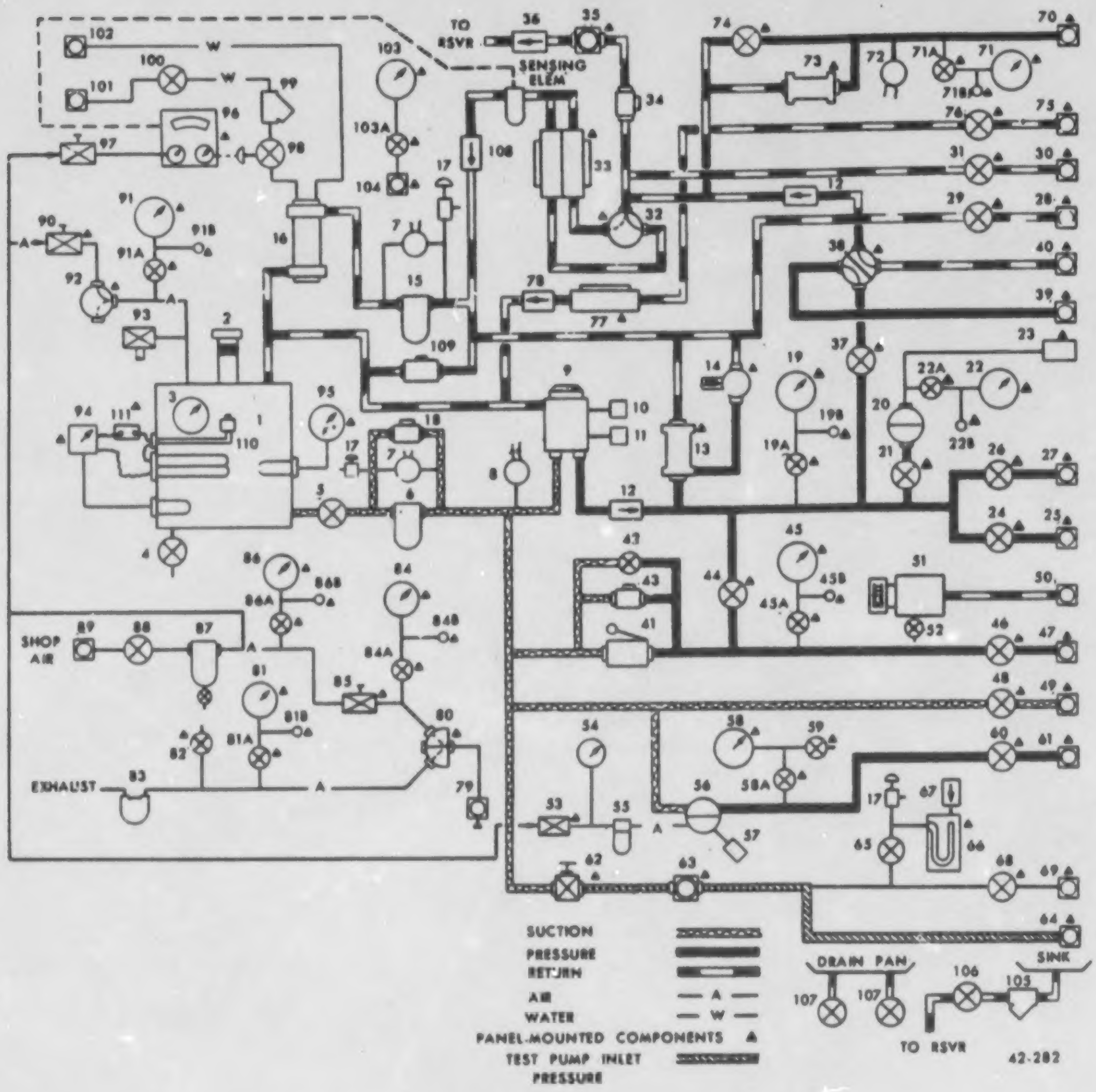
TO RSVR
SENSING ELEM
SHOP AIR
EXHAUST
DRAIN PAN
SINK
TO RSVR
42-282
SUCTION
PRESSURE
RETURN
AIR — A —
WATER — W —
PANEL-MOUNTED COMPONENTS ▲
TEST PUMP INLET PRESSURE

Figure 3. HCT-6 hydraulic component test stand schematic.

1. Reservoir
2. Reservoir Fill
3. Reservoir Level Sight Gage
4. Reservoir Drain Valve
5. Reservoir Shut Off Valve
6. Suction Filter
7. Differential Pressure Switch
8. Low Pressure Suction Switch
9. High Pressure Pump
10. Volume Control
11. Pressure Compensation Control
12. Check Valve
13. Stand Pressure Relief Valve
14. Solenoid Bypass Valve
15. Return Filter
16. Heat Exchanger
17. Air Bleed Valve
18. Filter Relief Valve
19. Component Test Pressure Gage
19A. Gage Shut Off Valve
19B. Test Port
20. Accumulator
21. Accumulator Shut Off Valve
22. Accumulator Charging Pressure Gage
22A. Gage Shut Off Valve
22B. Test Port
23. Accumulator Charging Valve
24. Component 1 Outlet Shut Off Valve
25. Component 1 Outlet
26. Component 2 Outlet Shut Off Valve
27. Component 2 Outlet
28. Component 1 Return
29. Component 1 Return Shut Off Valve
30. Component 2 Return
31. Component 2 Return Shut Off Valve
32. Flowmeter Range Selector
33. Flowmeter
34. Flowmeter Relief Valve
35. Flowmeter Relief Flow Indicator
36. Check Valve
37. Cylinder Circuit Shut Off Valve
38. Cylinder Circuit Selector Valve
39. Cylinder 1 Outlet
40. Cylinder 2 Outlet
41. Foot Pump
42. Bypass Valve
43. Relief Valve
44. Foot Pump Manifold Shut Off Valve
45. Foot Pump Pressure Gage
45A. Gage Shut Off Valve
45B. Test Port
46. Foot Pump Outlet Shut Off Valve
47. Foot Pump Pressure Outlet
48. Suction Outlet Shut Off Valve
49. Suction Outlet
50. Leakage Tank Inlet
51. Leakage Tank
52. Drain Cock
53. Air Pump Pressure Regulator
54. Air Gage
55. Lubricator
56. Air Driven Pump
57. Muffler
58. Air Pump Pressure Gage
58A. Air Pump Gage Shut Off Valve
59. Air Pump Outlet Vent Shut Off Valve
60. Air Pump Outlet Shut Off Valve
61. Air Pump Outlet
62. Pump Test Inlet Pressure Regulator
63. Suction Flow Indicator
64. Pump Test Suction Outlet
65. Pump Test Suction Manometer Shut Off Valve
66. Manometer
67. Float Check Valve
68. Pump Test Suction Test Port Shut Off Valve
69. Manometer Outlet
70. Pump Test Pressure Return
71. Pump Test Pressure Gage
71A. Gage Shut Off Valve
71B. Test Port
72. Pressure Switch
73. Relief Valve
74. Pump Test Throttling Valve
75. Scavenge Flowmeter Inlet
76. Scavenge Flowmeter Shut Off Valve
77. Scavenge Flowmeter
78. Check Valve
79. Test Pad Pressure Outlet
80. Test Pad Pressure Selector Valve
81. Test Pad Vacuum Gage
81A. Gage Shut Off Valve
81B. Test Port
82. Vacuum Regulator
83. Vacuum Pump
84. Test Pad Pressure Gage
84A. Gage Shut Off Valve
84B. Test Port
85. Test Pad Pressure Regulator
86. Air Inlet Pressure Gage
86A. Gage Shut Off Valve
86B. Test Port
87. Air Filter
88. Air Inlet Shut Off Valve
89. Air Inlet
90. Reservoir Pressure Regulator (Air)
91. Reservoir Pressure Gage
91A. Gage Shut Off Valve
91B. Test Port
92. Reservoir Pressure Selector Valve
93. Reservoir Relief Valve
94. Reservoir Heater Control
95. Reservoir Temperature Gage
96. Fluid Temperature Controller
97. Temperature Controller Air Pressure Regulator
98. Temperature Controller Valve
99. Strainer
100. Water Shut Off Valve
101. Water Inlet
102. Water Outlet
103. Accessory Pressure Gage
103A. Gage Shut Off Valve
104. Accessory Gage Port
105. Strainer
106. Sink Drain Shut Off Valve
107. Drain Pan Valve
108. Check Valve
109. Return Line Relief Valve
110. Reservoir Level Switch
111. Reservoir Heater Switch

Figure 4. Legend of callouts for figure 3.

When rotated in a clockwise direction, the bypass valve (14) will still be energized to the OPEN position by the pressure switch (72). No fluid will be circulated because the direction of rotation is opposite to the normal rotation of the internal high-pressure pump (9). Notice in figure 3 that the pump return circuit is protected from excessive pressures by the pump test relief valve (73). This relief valve can be adjusted (same as the internal high-pressure pump circuit relief valve) from 500 to 5000 psi. The pump test throttling valve (74) allows the operator to regulate the pressure in the pump test circuit. He does this by restricting the fluid flow to the return. From here the fluid flow is directed into the return circuit. This circuit will be covered at a later time.

1-12. The scavenge flowmeter circuit is basically a portion of the return circuit. The scavenge circuit is primarily used together with the pump test circuit. This circuit is shown in the upper right-hand portion of figure 3. It measures the fluid from the case drain port of the pump under test to check for internal leakage. The pump case drain port is connected to the scavenge flowmeter inlet (75). The fluid flow is controlled by the scavenge flowmeter shutoff valve (76). This valve also regulates the case pressure of the pump under test by restricting fluid flow. From here the fluid is directed to the scavenge flowmeter (77) which has a capacity of 0.14 to 1.5 gpm. Connect the pump case drain port to the component test return circuit inlet (30) if the flow is greater than 1.5 gpm. This will allow the pump case drain line flow to be directed to the larger flowmeter (33) used in this circuit. A check valve (78) is installed downstream of the scavenge flowmeter (77) to prevent reverse flow because of reservoir pressurization.

1-13. **Foot Pump Test Circuit.** This circuit allows the operator to perform static tests on components with pressures up to 6000 psi. The foot pump (41), is a single-suction single-action type of pump. It supplies fluid under pressure to the foot pump circuit pressure manifold. The relief valve (43) is installed to protect the system from possible overpressurization. It is factory set at 6000 psi and is not adjustable. A footpump bypass valve (42) is also installed to allow depressurization upon completion of testing. The footpump pressure can be directed to the component and actuator test circuits by opening the shutoff valve (44). The internal high-pressure pump will pressurize the footpump circuit if shutoff valve (44) is left open. The pressure in this circuit is indicated on the footpump pressure gage (45). Pressure is then directed to the foot pump outlet shutoff valve (46). This valve controls the flow to pressure outlet (47), which is connected to the component being tested.

1-14. The outlet (47) can be used to prime and bleed components by using reservoir pressurization. With the component connected to the outlet (47), open the bypass valve (42) and the shutoff valve (46). This allows reservoir pressurization to produce a fluid flow to the component being prprimed or bled. In other instances, this outlet (47) is used to measure the return or back pressures of many components being tested. For example, when testing a hand pump for proper operation, the suction port is connected to suction outlet (49). Place the suction outlet shutoff valve (48) to the OPEN position. The pressure port of the hand pump is connected to the footpump pressure outlet (47). This allows the footpump pressure gage (45) to indicate the pressure developed by the hand pump. The gage shutoff valve (45A) and the pressure outlet shutoff valve (46) must be in OPEN position during operations.

1-15. The footpump circuit may also be used to perform a leakage test on various components. The nonpressurized side of the unit being tested is connected to the leakage tank (51) through the inlet (50). The leakage tank (51) has a sight gage that indicates leakage from 5cc to 400cc, and 1 to 24 cubic inches. This tank is vented to prevent it from becoming pressurized and can be drained by opening the drain valve (52).

1-16. **High-Pressure Air Pump Circuit.** This circuit is schematically shown as being located just above the pump test suction circuit. It is used to perform static tests on hydraulic components at extremely high pressures. The air-operated pump circuit is capable of generating 25,000-psi hydraulic pressure when supplied with 100-psi air pressure.

1-17. Filtered air is supplied from the shop's air source. Pressure regulator (53) controls the output pressure of the air pump (56) and is adjustable from 0 to 100 psi. The pressure gage (54) indicates the air pressure applied. The lubricator (55), located between the pump air inlet and regulator provides lubrication for the air pump (56). It is serviced with 30-weight engine oil. The air pump is a differential piston-type unit having a ratio of 250 to 1. The exhaust port of the pump is also equipped with a muffler (57) to deaden the noise of the exhaust.

1-18. The air pump pressure gage (58) indicates the output pressure of the pump from 0 to 25,000 psi. The gage is connected to a gage shutoff valve (58A) and outlet vent shutoff valve (59). The outlet vent shutoff valve is used to release the pressure from the high- pressure test circuit. The flow from the high-pressure circuit is directed through shutoff valve (60) and air pump outlet (61) to which the component being tested is connected. The circuit uses a very small volume of fluid. When pressure is released, the fluid is dumped into the sink tray.

1-19. The high-pressure air pump circuit outlet (61) can also be used to prime and bleed units. This is done by using only reservoir pressurization to produce a fluid flow.

1-20. **Manometer Circuit.** This circuit is schematically located immediately above the pump test suction circuit. The manometer circuit is primarily used in conjuction with the pump test. It measures the inlet pressure or vacuum to the hydraulic pump under test. However, it can also be used independently to measure the vacuum of vacuum pumps.

1-21. The first unit in the manometer circuit is the pump test manometer shutoff valve (65). This valve allows the operator to isolate the circuit whenever desired. An air bleed valve (17) is installed in the manometer inlet line to remove air from this part of the circuit. The 30-inch U-type manometer (66) is half filled with mercury. It is direct reading and is calibrated from 0 to 30 inches Hg. Either pressure or vacuum can be measured with the manometer (66). A float-type check valve (67) is installed in the manometer outlet. It prevents the mercury from being blown out if the pressure exceeds 30 inches Hg. It also serves as a vent during normal operation.

1-22. The pump under test will generally be connected to the pump test outlet (64). The inlet flow will be controlled by the pump test inlet pressure regulator (62). Whenever the circuit is used independently, the component will be connected to the manometer outlet (69). The manometer outlet shutoff valve (68) controls flow to the manometer. The manometer should be isolated from the circuit anytime the suction pressure of the pump under test is greater than 30 inches Hg. This prevents damage since the manometer is only rated to 30 inches Hg.

1-23. **Return Circuit.** This circuit provides a path for return flow back to the reservoir from all the test stand circuits. It is equipped with associated valves that will clean, cool, and measure the return fluid. Any of the six return outlets shown in the upper right-hand portion of figure 3 can be used. The return fluid can be measured in the flowmeter (33) except when the flow is directed through the component No. 1 return inlet (28). Notice that this inlet is connected to the downstream side of the flowmeter (33).

1-24. The flowmeter (33) is actually two flowmeters in one housing. The smaller flowmeter of the dual unit has a range of 0.4 to 4 gpm. The larger has a range of 2.5 to 25 gpm. Fluid flow can be directed through either flowmeter by positioning the range selector valve (32) properly. As a safety precaution, always position this valve to the larger volume setting when shutting down the test stand. The two flowmeters are protected against excessive pressures by the flowmeter relief valve (34). It is set to relieve at 120 psi. The relief valve flow indicator (35) enables the operator to see when the relief valve opens. Check valve (36) prevents reverse flow resulting from reservoir pressurization. This line is connected directly to the reservoir.

1-25. Notice that downstream of the flowmeter, a sensing element measures the temperature of the fluid. From here the fluid is directed to the return line filter (15) that removes any foreign matter. The filter is equipped with a differential pressure switch (7). Anytime the filter becomes clogged, it causes a light on the control panel to illuminate. The bleed valve (17) allows entrapped air to be bled from the return circuit. Since the filter is not equipped with an internal bypass, a relief valve (109) is installed. The relief valve is set at 50 psi.

1-26. Before entering the reservoir, the fluid passes through a heat exchanger (16). It is a water-cooled shell-and-tube type. The fluid passes through the heat exchanger and is cooled by the flow of cooling water. The temperature control circuit maintains the desired temperature.

1-27. **Temperature Control Circuit.** This circuit is schematically shown in the upper left-hand corner of figure 3. The temperature control circuit is designed to maintain the fluid at a constant temperature of 100° F. to 180° F. This is done by cooling the fluid with the heat exchanger (16) or heating the fluid with the heaters in the reservoir.

1-28. The fluid temperature controller (96) is a pneumatic indicating-type assembly. It is equipped with two air pressure gages and a temperature gage. This temperature gage is connected to the return line sensing element. It indicates the temperature of the fluid passing through the return circuit. The input gage (left) indicates the input air pressure, which is normally maintained at 20 psi, controlled by the air pressure regulator (97). The output gage (right) indicates the amount of air pressure applied to the diaphragm of the air-operated shutoff valve (98). Shutoff valve (98) controls the flow of cooling water to the heat exchanger (16).

1-29. Water for the heat exchanger enters the test stand through the inlet provided (101). Water inlet valve (100) is used to turn the water on and off. This valve should always be open except when maintenance is being performed on the stand. The water flows through water pump (99), which is equipped with a removable 60/80 wire mesh screen and a drain plug. The water then flows through the heat exchanger (16) and back out of the test stand through the outlet (102). The capacity of the water supply to the stand must be 15 to 20 gallons per minute.

1-30. **Air Pressure Circuit.** This circuit is schematically shown in the left-hand portion of figure 3. The air pressure circuit supplies shop air to the four pressure regulators built into the test stand. Shop air should always be at least 90 psi.

1-31. Air at shop pressure enters the stand through inlet (89), flows through a shutoff valve (88), filter (87), and four pressure regulators. The air pressure at this point will be shown on the air inlet pressure gage (86). Notice that this gage, like all other gages on the stand, is equipped with a shutoff valve (86A) and a test port (86B).

1-32. The reservoir pressure regulators, air pump pressure regulators, and temperature controller pressure regulators have been covered. So they need no further explanation. The fourth air pressure regulator is the *test pad* pressure regulator (85). It is schematically shown in the lower left-hand corner of figure 3. The operator adjusts it to the pressure prescribed for the pump undergoing the shaft seal test. The pressure is indicated on the test pad pressure gage (84). From here the air pressure is directed to the test pad selector valve (80). This valve allows the operator to connect the test pad outlet (79) to pressure, vacuum, or atmosphere.

1-33. **Vacuum Circuit.** This circuit is schematically shown just below the air pressure circuit. The vacuum circuit is used when testing the pump shaft seal. Vacuum pressure is generated by a rotary-type vacuum pump (83). This pump can generate 27 inches of Hg vacuum. It is equipped with an automatic oiler that is serviced with 30-weight engine oil. Vacuum pressure is applied to the test pad outlet (79) through the VACUUM position of the test pad selector valve (80). The level of vacuum pressure in this circuit is controlled by the position of the vacuum regulator (82). When this valve is opened, atmosphere can enter the system, thus reducing the level of vacuum. The vacuum pressure is shown on the test pad vacuum gage (81) which reads from 0 to 30 inches of Hg vacuum.

1-34. **Accessories.** In the upper left center of figure 3, you will find an accessory pressure gage (103). The gage can be used to measure the case pressure of pumps or the back pressure of units being tested. It can show the pressure at any point that the operator chooses to connect it to. He uses the accessory gage port (104) as the connection point. The gage shutoff valve (103A) must be open before the gage registers.

1-35. The lower right-hand portion of figure 3 schematically shows a test stand sink and a test stand drain pan. A perforated sink pan is located above the test stand sink. This allows the operator to drain all the fluid from the components when the testing has been completed. All of the fluid drained into the sink is directed back to the reservoir through the strainer (105) and the shutoff valve (106). The sink outlet sump is equipped with a metal screen filter. The drain pan, with two drain valves (107), is located in the bottom of the test stand. It catches any fluid that is spilled or drained while maintenance is being performed on the stand.

1-36. **Operating Instructions.** You should have little difficulty in operating the HCT-6 test machine. Knowing the various test circuits is a great asset in using the machine. Therefore, we shall use the machine's schematic diagram (fig.3) during our discussion of its operation. Also, this will give you a better understanding of why the various valves, etc., are being turned. Bear in mind that there are various procedures that can be used when operating the machine. The procedure used depends primarily on what types of units are going to be tested. Thus, we shall make our discussion on the operation of the test machine as simple as possible.

1-37. *Setting up the test machine.* When you test a unit, one of your first concerns is to select the proper connecting hose or tubing. The hose used must be able to withstand the pressure used during the testing operation. Otherwise, you might find yourself cleaning up hydraulic fluid that sprayed on the ceiling and walls of the shop. When all of the hookups have been made and the machine has been checked for irregularities, you are ready to set it up. First, open all gage shutoff valves and the cylinder circuit shutoff valve. Open the reservoir shutoff valve (5), the water shutoff valve (100), and the air inlet shutoff valve (88). All other valves on the instrument panel should be closed. Position the actuating cylinder test circuit selector valve (38) to the FLOWMETER RETURN position. Set the flowmeter range selector (32) to the 2.5 to 25 gpm position. This will allow the fluid output of the high-pressure pump (9) to be directed to the reservoir through the flowmeter (33). This will be necessary when you adjust the volume output later on. Using the air pressure circuit, pressurize the reservoir (1) to 25 psi; then, depressurize the reservoir and check the fluid level. The purpose of this operation is to insure that all lines are completely filled with fluid. After this has been done, repressurize the reservoir to 60 psi. You are now ready to start the machine.

1-38. *Starting.* At this point, close the main circuit breaker and turn on the master switch. Now turn on the 30-volt-dc power circuit and insure that a 27.5-volt minimum is available. Place the control switch for the solenoid-operated bypass valve (14) in the OPEN position. This insures that the high-pressure pump (9) will start under a no-load condition. Using the counterclockwise button, start and stop the high-pressure pump and check rotation. Turn on the reservoir heater switch (111) and check to see if the green light on the control panel lights. Return the switch to the OFF position and set the thermostatic heater control (94) to 70° F. Adjust the fluid temperature controller (96) to the desired temperature. Reposition the control switch for the solenoid-operated bypass valve (14) to the OFF position.

1-39. Start the pump and open the bleed valves (17) on both filters, and bleed the system of all air. After this is dnone, adjust the high-pressure pump volume control (10) to the volume required. Next, adjust the test stand relief valve (13). To do this, turn the pressure compensator control (11) all the way in. Then close the cylinder test circuit shutoff valve (37). Now adjust the relief valve (13) from 200 to 400 psi higher than the pressure required for the unit being tested. Readjust the compensator control (11) to the test pressure required for the unit being tested. Open the actuating cylinder test circuit shutoff valve (37). This depressurizes the pressure manifold so that the operator can connect the compeonent to be tested. You are now ready to perform the various tests that are required. If you desire additional information on the HCT-6, refer to Technical Order 33A2-2-35-1.

2. Portable Hydraulic Test Stands

2-1. To insure proper operation of hydraulic systems you must be able to test entire systems. You also be able to test operation of each individual unit while it is in the system. It would be ideal to test them under actual flight conditions. But, the closest we can come to this is to test them on the aircraft itself itself while on the ground. To do this, we use a portable hydraulic test stand. We call it a test stand because with it we can make operational tests of the aircraft systems and components. It replaces the engine-driven pumps as the source of hydraulic pressure and volume.

2-2. If you are working where there is electric power, you will probably use an electrically driven stand. Where there is no electric power, you must use a gasoline engine-driven test stand. Numerous portable test stands are produced, but we'll discuss only the ones in most common use today. They are of the MK and MJ series. These two types are generally identical except for their power source. The MK series is driven by an electric motor while the MJ series is driven by a gasoline engine. Dash numbers after the MK and MJ denote successive models. We will cover the MK-3 in this section. We will not cover an MJ series unit because the operation of its test stand portion is no different from that of the MK series.

2-3. **General Construction of the MK-3 Stand.** The MK-3 is a portable, multisystem, electric motor-driven unit. It is designed to supply hydraulic pressure where electric power is available. This test stand is capable of testing hydraulic systems that operate at pressures up to 6000 psi. It is connected directly into the aircraft hydraulic system, which it supplies with both fluid pressure and volume. This allows the system to be pressurized and operated in a simulated flight condition. Your test results can be checked against instructions contained in the aircraft TO.

2-4 The MK-3 portable test stand is shown in figure 5. The stand is covered by a weatherproof steel cabinet bolted to a trailer. Hinged doors in the cabinet provide access to the various components. The trailer assembly consists of four wheels with pneumatic tires and coil springs. A hinged tow bar and steering assembly is attached to the front wheels. A mechanical parking brake operated by a single control provides brake application on two rear wheels. Power for operation of all systems is provided by six electric motors. Two motors drive the main system pumps. Two more drive the test system boost pumps and cooling fans. Another drives the fill-and-bleed system pumps, and the last motor drives the air compressor. Electrical power for these motors comes from one central point. The electrical requirements are 220-400 volts, 3-phase, 60-Hertz. There are *two identical, independently operated hydraulic systems.* There are *two auxiliary single systems, the fill-bleed* an *air systems.*

2-5. **Principles of Operation.** Study figure 6 and the nomenclature in figure 7. You will see that from the reservoir (1) down, there are duplicate hydraulic systems. They are the two independent systems we mentioned in the last paragraph. They may be used to make an aircraft operational check. They can also serve to fill or flush the aircraft system. The two systems may be operated together or separately. They can operate using test stand fluid or fluid from the aircraft reservoir. For high-flow tests the two systems are manifolded together.

2-6 For an aircraft check the following flows and procedures occur. Boost pump (6) draws fluid from either the stand reservior (1) or the aircraft system. The positions of the reservior selector valve (28) determines the source. The boost pump delivers boost pressure to the main pump (13) through filter (5). The main pump delivers fluid to the aircraft through check valve (14). From the check valve it passes through the high pressure filter (20) and the

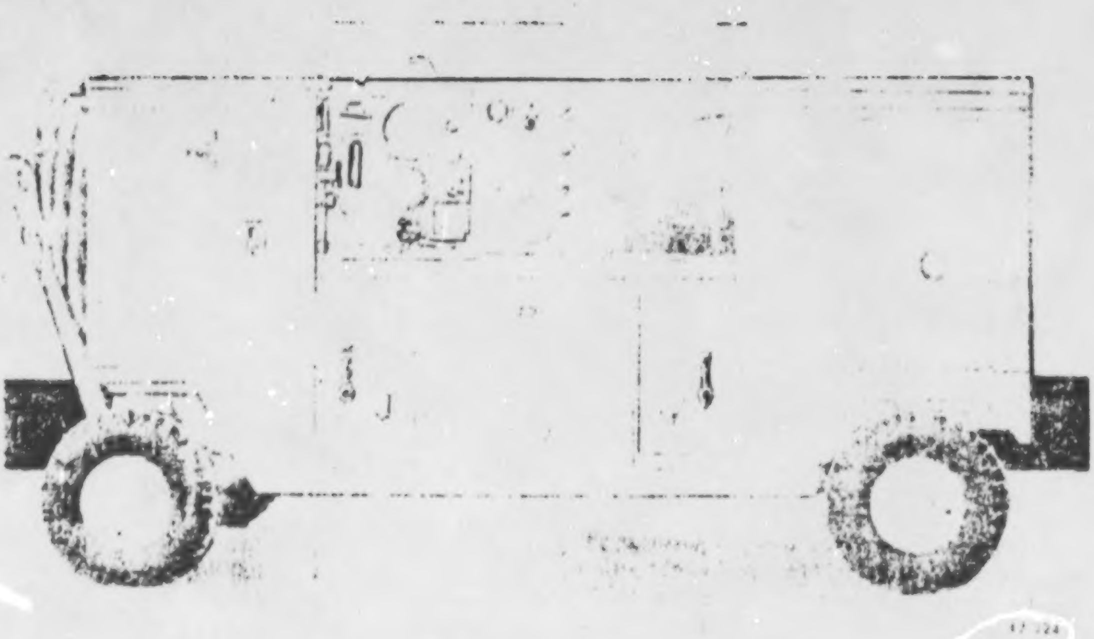

Figure 5. MK-3 dual-system hydraulic test stand.

needle-type flow control valve (21).

2-7. Three relief valves provide protection. They are the thermal relief valve (49), boost (lines) relief valve (9), and high-pressure (lines) relief valve (18). Needle-type dump valve (26) is used to manually relieve system pressure to return.

2-8 The main pump (13) is equipped with a volume control and a compensator control.

2-9. The compound gage (8) is equipped with a gage selector valve (7) and a calibration outlet (44). High-pressure gage (17) has a gage dampener (15), a needle-type shutoff valve (16), and a calibration outlet (44).

2-10. The Fahrenheit (temperature) gage (12) and the thermoswitch (11) attached to a manifold (10), give fluid temperature indication. The cooler bypass selector valve (24) and the oil cooler (25) provide temperature control. The cooler bypass selector valve provides control of fluid temperature. The thermoswitch (11) sounds a warning horn if fluid temperature goes too high. Pressure switch (50) measures boost pump pressure. It shuts down the system if the pressure to the main pump (13) drops below 90 psig.

2-11. Check valve (27) bypasses boost pump (6) to prefill the boost system. Differential pressure switch (19) can energize a filter indicator pilot light. It does this if the high-pressure filter (20) should clog. The manifold selector valve (23) is used to combine or separate the two test systems. The sight tubes (22) are used to check for air bubbles in the fluid returning from the aircraft.

2-12. *Fill and bleed system.* The single fill and bleed system is used to fill, flush, and bleed the aircraft system. When the pushbutton on the filling valve (3) is depressed, the valve opens and a built-in switch closes. Fill pump (30) starts and delivers fluid from the reservoir through the check valve (31) and filter (32). The fill system pressure gage (33) measures pressure drop across filter (32) as well as fill system delivery pressure. The fill system relief valve (2) limits maximum pressure. Fluid flows on towards the aircraft through the test system return line. When combination bleed valve and sight tube (4) is depressed, a line from test system filter (5) to reservoir (1) is opened.

2-13. *Air system.* This system pressurizes the test stand reservoir and provides compressed air to the aircraft. Compressor (34) delivers pressure to the air receiver (47). The air unloader valve (48) will unload the air pump when system pressure is achieved. Compressor pressure also goes on to the compressor air pressure regulator (35). From there it goes to either air outlet port (43) or to the reservoir air pressure regulator (39). The reduced pressure flows on to the reservoir pressure dump valve (40). From there it can be dumped through vent filter (41) or sent on into reservoir (1). Relief

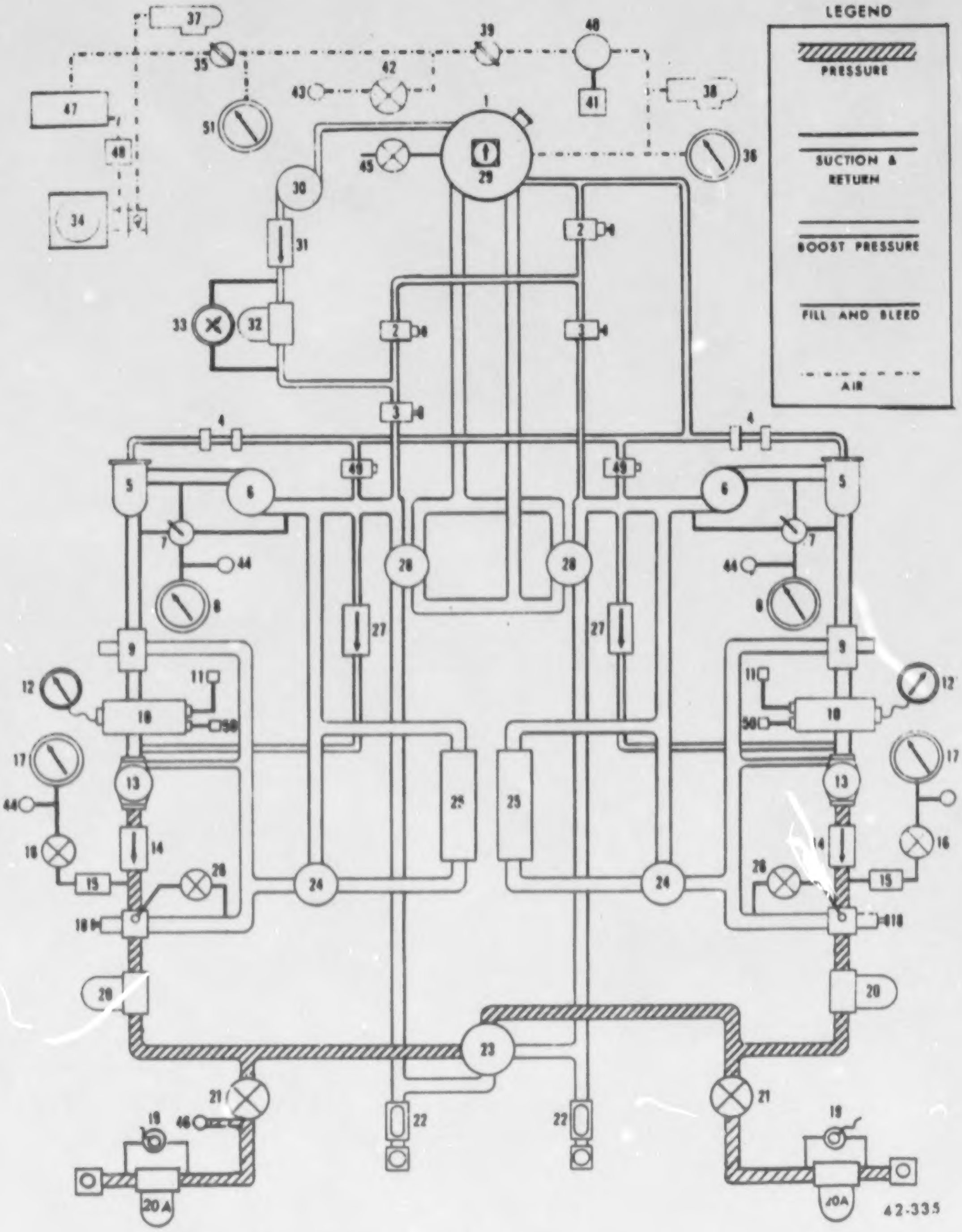
LEGEND
PRESSURE
SUCTION & RETURN
BOOST PRESSURE
FILL AND BLEED
AIR
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Figure 6. MK-3 hydraulic and pneumatic shcematic.

1. Reservoir
2. Fill System Relief Valve
3. Filling Valve
4. Bleed Valve
5. Suction Filter
6. Boost Pump
7. Gage Selector Valve
8. Compound Gage
9. Boost Relief Valve
10. Manifold
11. Thermoswitch
12. Fahrenheit Gage
13. Main Pump
14. Check Valve
15. Pulsation Dampener
16. Gage Shutoff Valve
17. High Pressure Gage
18. High Pressure Relief Valve
19. Differential Pressure Switch
20. Pressure Filter
21. Flow Control Valve
22. Sight Tube
23. Manifold Valve
24. Cooler Bypass Valve
25. Cooler
26. Dump Valve
27. Check Valve
28. Reservoir Selector Valve
29. Reservoir Level Gage
30. Fill Pump
31. Check Valve
32. Fill System Filter
33. Fill System Pressure Gage
34. Compressor
35. Compressor Pressure Regulator
36. Reservoir Air Pressure Gage
37. Relief Valve
38. Relief Valve
39. Reservoir Pressure Regulator
40. Reservoir Pressure Dump Valve
41. Vent Filter
42. Air Shutoff Valve
43. Compressed Air Outlet
44. Gage Test Outlet
45. Reservoir Drain Valve
46. Static Test Port
47. Air Receiver
48. Unloader Valve
49. Thermal Relief Valve
50. Pressure Switch
51. Air Outlet Pressure Gage

Figure 7. Legend of callouts for figure 6.

valves (37 and 38) limit the pressure to the stand reservoir. Reservoir pressure is read on its gage (36).

2-14. **Preliminary adjustments.** Refer to figures 8 and 9. Before you connect the test stand to the aircraft,make the following check. Make sure that the stand is wired for the same voltage as the power source and that all circuit breakers are on. Connect the electric plug to power source; if correctly phased, sight indicator lights will come on. Check reservoir for minimum of 20 gallons. Set gage shutoff valves (10) one-fourth turn from fully closed position to protect from surges during starting. Turn gage selector valves (4) to filter inlet position and compensator controls (9) at approximately the midway position. Close both flow control valves (13), and relief valves (12) at full in position. Dump valves (16) both should be set at one-half turn from fully closed. This prevents rapid pressure buildup. Adjust volume controls (7) to desired as showned on indicators (8). Set reservoir selector (item 28 in fig. 6) to ship reservoir position and reservoir pressure dump valve (21) to vent. Compressor pressure regulator (18) should be opened halfway. Open both fill system relief valves (1) to help protect from pressure buildup in start position. Now valves are all in position so that the stand can be used to set up test pressure on fill system.

2-15. The stand should be bled before it is connected to the aircraft. To do this depress No.1 system fill valve (2) and adjust No. 1 fill system relief valve (1) to 150 psig. The pressure is indicated by a red pointer on the fill system pressure drop gage (17). Continue to depress filling valve until 50 to 100 psig is indicated on the compound gage (5). To allow air from the system to return to stand reservoir, depress No.1 system bleed valve (3). To bleed No. 2 system, follow the same instructions as for No. 1. The stand is now ready for testing the aircraft system.

2-16. **Pre-start.** Place both reservoir selector valves (item 28 in fig. 6) in stand reservoir position. Place reservoir pressure dump valve (21) to pressurized position. Place gage selector valve (4) in filter outlet position. Adjust reservoir pressure regulator (20) to obtain 20 psig and adjust compressor regulator (18) to obtain 70 psig. Next, open both flow control valves (13). Press button on pump motor switch (26) on No. 1 system until 90 psig is indicated on compound gage (5). If both systems will be operated, allow at least 1 minute delay before starting second system. This will insure that

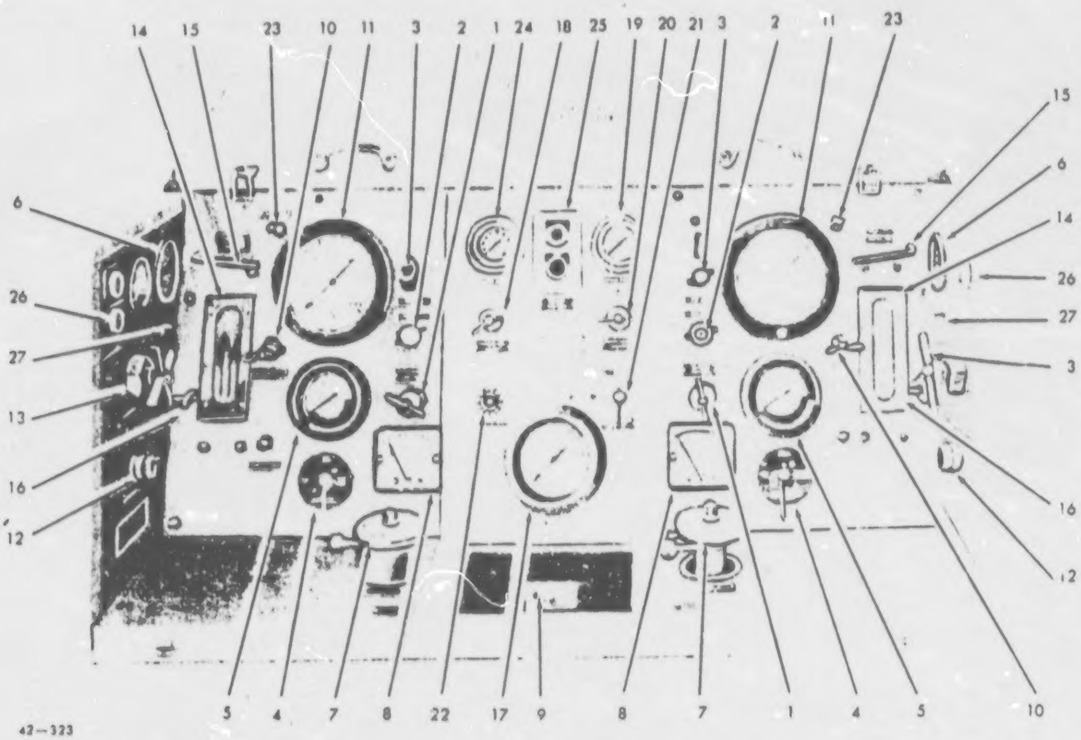

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Figure 8. MK-3 control panel.

1. Fill System Relief Valve
2. Filling Valve (Pushbutton Valve and Switch)
3. Bleed Valve (Valve and Sight Gage)
4. Gage Selector Valve
5. Compound Gage
6. Fahrenheit Gage (Temperature)
7. Volume Control
8. Volume Indicator
9. Compensator Control
10. Gage Shutoff Valve
11. Pressure Gage (0-6000 PSIG)
12. Hi Press Relief Valve
13. Flow Control Valve
14. Sight Tube
15. Cooler Bypass Valve
16. Dump Valve
17. Fill System Press Drop Gage
18. Compressor Press Regulator
19. Reservoir Air Pressure Gage
20. Reservoir Pressure Regulator
21. Reservoir Pressure Dump Valve
22. Air Outlet Shutoff Valve
23. Gage Test Outlet
24. Air Outlet Pressure Gage
25. Compressor Motor Switch
26. Pump Motor Switch
27. Filter Indicator

Figure 9. Legend of callouts for figure 8.

adequate power is available from the source.

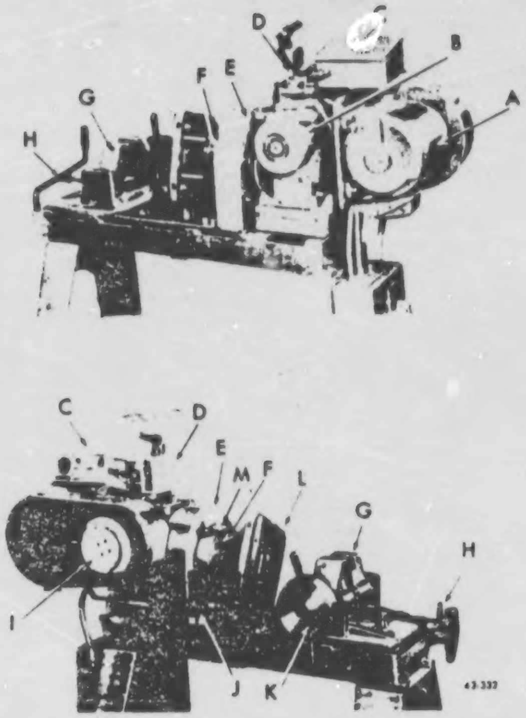
2-17. Now depress bleed valve (3) until clear fluid flows through bleed sight tube, insuring that system is free of air. When system has been bled, close dump valves (16). Then slowly close flow control valves (13) of No. 1 system, until gage (11) reads 500 psig. With lines connected in recirculate hookup, the pressure and return lines are connected. Open No. 1 flow control valve and allow oil to circulate for 2 or 3 minutes. Repeat with No. 2 system. The fluid should be free of air and circulated through the filter enough to ready for hookup to aircraft. Open dump valves (16) and close flow control valve (13) and press stop button for pump motor. If the pressure filters (item 20A, fig. 6) should clog, the filter indicator (27) will light up.

2-18. Uncouple the hose from the recirculation hookup, being careful to depressurize the reservoir. Moving dump valve (21) to vent will reduce oil spraying during disassembly. The stand can now be connected to an aircraft for testing. Items 22 through 25 are of the air pressure system. They are used for pressurizing the stand and aircraft reservoirs.

2-19. Once connected, operating instructions are the same as previously described; only the following changes are necessary. Adjust the pump compensator to the desired pressure for the aircraft under test. *Example:* 3000 psi. The relief valve should be set about 250 psi above desired operating pressure. This prevents damage to the system being tested. A caution—in positioning the reservoir selector for test, don't move it with stand running and flow control valve open. This prevents possible damage to the reservoir from system pressure during selector positioning. Be sure when operating this, or another, test stand to consult and follow proper technical orders.

3. Hose and Fitting Assembly Machine

3-1. The unit used in this section is shown in figure 10. It allows the mechanic to rapidly assemble or disassemble standard hose fittings. Once you have set up your machine, you can process hose assemblies rapidly and with little effort. Compare this to the hand method described earlier. The unit shown in figure 10 can accommodate medium pressure hose fittings size 3 through 32. In the high-pressure



A.	Motor
B.	Speed reducer
C.	Control box, torque limiter
D.	Control switch
E.	Clutch
F.	Overriding head
G.	Carriage and vise assembly
H.	Lever, vise carriage
I.	Handwheel, transmission
J.	Handle, brake lever
K.	Handwheel, vise
L.	Chuck
M.	Brake

Figure 10. Hose and fitting assembly machine.

hose fitting only sizes 4 through 16 can be used. With this unit you can also handle the flange, elbow, male pipe and swivel-type fittings.

3-2. **Construction.** This machine is powered by a 1½ hp electric motor (A). The electrical requirements are 220/440 volts, 3-phase, 60-Hertz ac power. The motor drives a speed reducer by means of a V belt. The three step sheaves to the speed reducer (B) provide for output speeds of 40, 90, and 140 rpm. The machine is controlled by the three-position switch (D). The positions are FORWARD, REVERSE and OFF. A pushbutton switch located in the control handle on the top of the control switch deenergizes the torque limiting device. The torque limiter automatically senses predetermined torque valves and allows the prescribed gap setting. Control box C, operating on 110 volts ac, controls the energizing and operation of the torque device. The control switch on this box has three positions, RUN, OFF and JOG. A dial provides a means of selecting proper cutoff torque. A chart is provided for the calibration of the proper selection setting for each size fitting.

3-3. Brake M, operated by lever J, controls rotation of overriding head assembly F. Chuck L is also part of the head assembly and is used to hold fittings. The overriding head may be engaged two ways:

- By operating the direct-drive lever on the head assembly.
- By engaging the torque limiting device.

3-4. Carriage and vise assembly G includes a vise for holding fittings and hose. The handwheel K opens and closes the vise. Operating lever H controls horizontal movement of the carriage. Transmission handwheel I provides for manual rotating alignment of the chuck. The clutch E transmits torque to the chuck when engaged.

3-5. **General Operating Instructions.** Before this machine is set up for operation, make sure that all electrical power is off. Then select the proper mandrel drive of the overriding head, being careful not to damage the threads. Next, insure that the chuck has the proper jaws installed. Position the mandrel until the "B" nut is totally engaged in the jaws. Adjust the jaws to the fitting, providing clearance for the "B" nut of approximately 1 inch. Never use an extension on the chuck wrench, since excessive pressure may damage the chuck jaws.

3-6 Disengage the overriding head by positioning the direct-drive lever to DISENGAGE. This is a V-shape lever on the overriding head (not shown). It allows the chuck to turn, or only the mandrel, depending of its position.

3-7. Switch the machine control switch to FORWARD and apply light brake pressure to stop rotation of the head. Insert the nipple and nut assembly onto the mandrel. Release the brake when the head starts to turn. This indicates that the nipple is bottomed on the mandrel and that the nut is tight.

3-8. Place the hose and socket assembly in the carriage vise with socket extending ⅛ to ¼ inch. Tighten the jaws of the vise securely on the socket. Lubricate the nipple and hose bond freely.

3-9. Move the carriage vise forward until the nipple enters the hose bond and the nipple threads engage the socket. The overriding head is still rotating at this time in the FORWARD position. Allow the nipple to thread into the socket until a gap of 1/16 inch exists between them. Do not allow the pieces to be tightened to the point that they contact each other. This would not give any freedom for "B" nut rotation during installation of hose.

3-10. When the proper clearance is reached, switch the machine to OFF. Apply the brake and switch the machine to REVERSE; the assembly should back off the mandrel. When the nipple assembly is clear of the mandrel, switch the machine to OFF. Now repeat the same process to the opposite end of the hose.

3-11. For all types of machines, consult the proper TO for further instruction. To insure proper operation and safety, be sure to read the TO before using this hose assembly machine.

4. Jacks

4-1. When it becomes necessary to jack any aircraft, first consider the element of safety. Before you attempt this operation, consult the maintenance TO for the particular aircraft. There is always a chance that the aircraft may slip and fall from the jacks, with disastrous results. Flatheads such as the individual shown in figure 11 are now 6 feet under because of their carelessness.

4-2. Aircraft jacks are generally classified as either wing or axle jacks. Some have a fixed height; others are adjustable.

4-3. **Wing Jacks.** There are several different types of wing jacks to fit various needs. The type most frequently used is the tripod jack. All jacks of this type are basically the same in operation and structure. Some are larger and possess more weight-lifting ability than others. So, for discussion purposes, we have chosen the 6-ton-capacity-type B-1A jack (see fig. 12). It is representative of almost all tripod jacks.

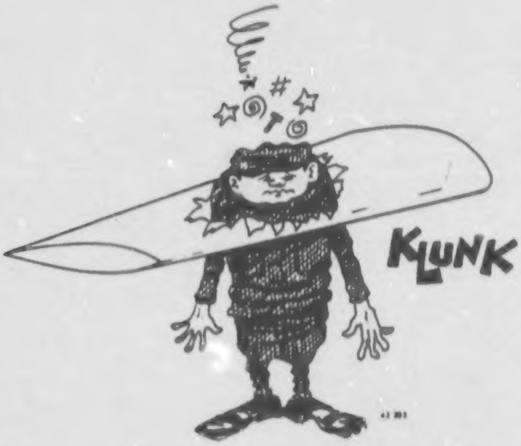
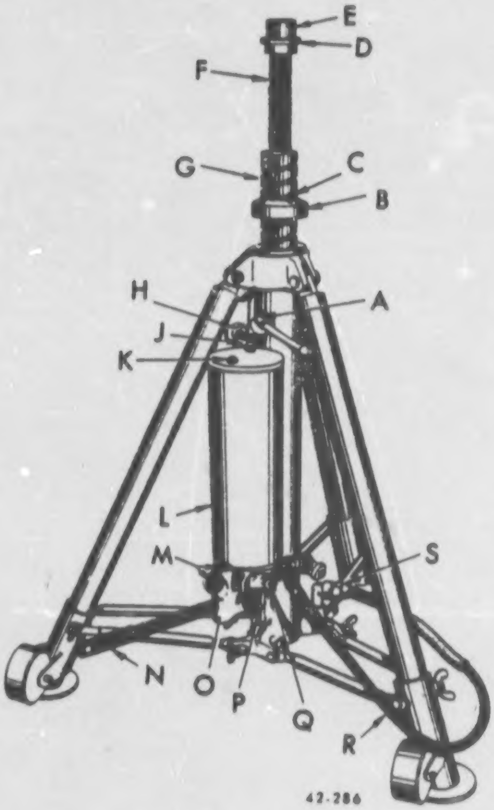


Figure 11. Result of improper use of aircraft jacks.



A.	Reservoir locking cam
B.	Locknut
C.	Setscrew
D.	Extension locknut
E.	Jack pad
F.	Extension screw
G.	Ram
H.	Jack pad adapter
J.	Air vent
K.	Filler plug
L.	Reservoir
M.	Pump handle socket
N.	Pump handle
O.	Pump handle fulcrum assembly
P.	Removable hinge pins
Q.	Needle valve
R.	Flexible metal and rubber hose
S.	Quick-disconnect fittings

Figure 12. B-1A wing jack, 6-ton.

4-4. The B-1A is used as a wing jack for fighter and trainer-type aircraft. It can also be used as a nose and tail jack when its height and capacity are suitable. It is a portable, self-contained, hydraulically operated unit. The jack consists of a basic hydraulic lifting unit mounted in the center of three tubular steel legs. It is operated by a pumping unit which is connected to the lifting unit by metal and rubber hose R. Extensions for the tripod base and for the ram may vary the height of the jack. Be sure to consult the TO on their use.

4-5. The pumping unit consists of reservoir L and a simple hand pump. Under normal conditions, the pumping unit is attached to the lifting unit. It can, however, be detached from the cylinder and operated on the ground. Locking cam A secures the top of the unit, and hinge pin P secures the bottom. The speed of operation is determined by two positions of handle N in sockets M. Each socket has a different relationship to fulcrum O. The top position gives the greatest travel per stroke to the lifting ram. This position is used for quick raising when positioning the jack. It can also be used for loads up to half of the jack capacity. The lower position, which provides the greatest lifting power, is used when the jack is under full load.

4-6. The pump itself is mounted in the bottom of the reservoir. It is a *single*-action type of pump. Fluid is drawn into the pump as the piston moves away from the suction port. It then produces fluid pressure when the piston is forced in. The reservoir is a cylindrical steel container capable of holding 1 gallon of hydraulic fluid. Filler plug K and air vent J are located on the top of the reservoir. Remove the filler plug and check the fluid level before each jacking operation. The air vent is used to prevent a vacuum from being created in the oil reservoir when oil is withdrawn. The air vent is opened by loosening a knurled knob before jacking or lowering. It should be open at any time the jack is under load. Internal pressures can be built up as a result of the thermal expansion of the fluid and air. To raise the jack cylinder, close needle valve Q and stroke pump until desired level is reached.

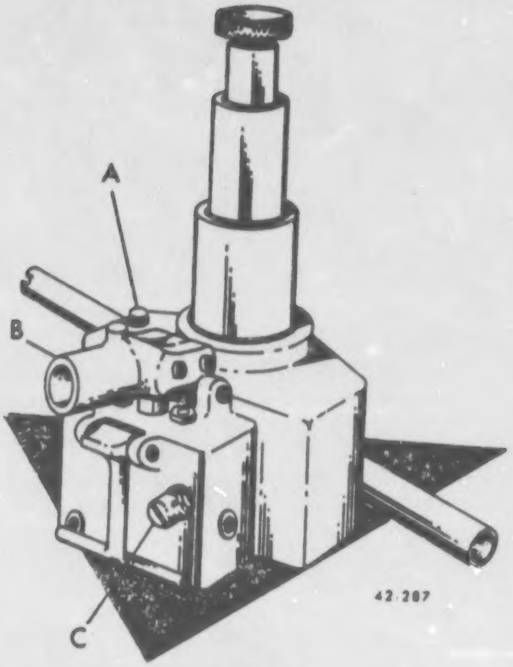
4-7. Now that you know how to get the jack up, let's see how you get it down again. At the bottom of the reservoir, needle valve Q is part of the pump casting. This needle valve, when open, bypasses the pump. This allows the fluid to return to the reservoir from the cylinder. This releases the pressure in the lifting unit and allows the ram to settle.

4-8. Fluid flowing from the pump tp the cylinder passes through a flexible metal and rubber hose. It is equipped with quick-disconnect fitting S to reduce fluid loss during maintenance.

4-9 The primary part of the cylinder assembly is lifting ram G. It is an extension of the piston in the cylinder, and it houses extension screw F. Cut into the outer surface of the ram are steeply pitched threads. Locknut B can rotate up or down the threads. When the ram is being raised,the weight of the locknut will cause it to rotate down the grooves and remain on top of the cylinder. If the ram lowers, the locknut will bind between the grooves and the cylinder top and will not rotate. The locknut is merely a safety device to prevent accidental lowering. The nut should always be screwed down against the cylinder except when lowering the load. In this event, the locknut should be rotated up the ram by hand to keep a clearance between it and the cylinder. This allows the ram to lower, but is ready to lock should a pressure failure occur. Setscrew C permits locking the locknut to the ram. This should be used when one leaves the jack standing standing under a load. The ram is guided in its travel by an upper bearing in the top of the cylinder assembly and a lower bearing on its lower end. It is prevented from turning by means of the ram key, which is located in the upper bearing. The key fits in a veritical slot on the ram (not shown). The fit of the bearing is very close. Any burrs or deformation on the ram can prevent it from lowering smoothly. The outer surface and the steeply pitched grooves must be kept clean and smooth. The should be used when one leaves the jack standing under a load. The ram is guided weight. Dirt on the ram's surface or burrs on the groove edges and keyway will scratch and mar the upper bearing.

4-10. The screw extension is also equipped with locknut D. It should be screwed down to the top of the ram as soon as the screw has been screwed out the desired distance. It too, is a safety device. Jackpad E fits the jackpads on many aircraft. If it doesn't, jackpad adapter H placed in the jackpad will meet the need.

4-11. Sometimes air may get under the ram. If this happens, the jack will not work right. Because the ram is heavy.the air under it must be compressed before the ram moves. After the ram reaches the load, the air must be subjected to more pressure in order to lift the load. Each time pressure is applied against the air, pump strokes are lost. The simplest remedy for this situation is to pump up the ram a short distance. Then lay the jack on its side with the hose connection up. Disconnect the hose at the cylinder and hold open the cylinder side of the quick-disconnect valve. Now press in on the ram. This will ezpel the air from the cylinder assembly. Bleed the air from the hose by holding the hose side of the quick disconnect open. Then operate the pump slowly. When all air is expelled, reconnect the hose.



A. Air vent
B. Pump handle socket
C. Needle valve

Figure 13. Axle jack.

4-12. **Axle Jacks.** Axle jacks are often used instead of tripod jacks when brake work or tire repair is being performed. There are several types of axle jacks. Figure 13 shows a 5-ton jack which is typical of most hydraulically operated axle jacks. The type to use depends on how high or how heavy the load is, and how much clearance between the load and the ground. Of course you wouldn't use a jack that has a closed height of 6 inches to raise the axle of a B-52 gear. When it is fully extended, it probably wouldn't even reach the axle. Therefore, you must use a little common sense. The best thing to do is to select a jack that is just a little lower than the axle when the jack is closed. Then there should be no problem.

4-13. Like the tripod jacks, the axle jack has a screw extension in the center ram which can be extended for greater height. Notice also that there are three rams instead of one. Because of this, a small and compact jack can be made to extend a great distance. Once again, the pump is built into the reservoir. However, in this jack the reservoir is the base of the ram section. In figure 13 you can see that the handle, behind the jack, fits into the pump handle socket (B). The handle is equipped with notches in the pump end which fit the knobs on the needle valve head. This makes opening and closing of the needle valve (C) easier. There is also an air vent (A), which should be open during extension, lowering, and when under load. At all other times this air vent should be closed. To service the reservoir, lower the jack completely and remove the air vent and plug (A). Place a funnel in the opening and fill with hydraulic fluid. Remove funnel and replace the plug; if the jack is not going to be used, close the air vent.

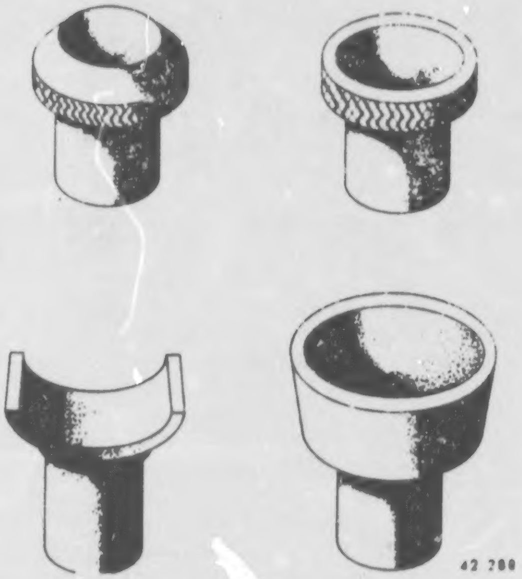


Figure 14. Jack pads.

4-14. **Jack Pads.** Jack pads are adapter units which allow the jack to fit the jackpoint on the aircraft. They lessen the likelihood of the jack's slipping and damaging the aircraft. Figure 14 shows types of jack pads which fit into the socket of the jack extension screws. (E in fig. 12). Other jack pads are attached to the under side of the aircraft. They are points shaped to fit into the pads on the jacks. The reason for having a variety of jack adapters is to permit the use of one jack for a number of aircraft. All aircraft do not necessarily have the same type of jack pad. The aircraft may have its jack pads permanently attached, or it may require that they be attached for jacking. Some of the aircraft pads may be bolted on; others may snap into place. Still others screw on. When not in use, some aircraft jack pads are stored in the aircraft; others must be stored in the supply rooms of the home base. The TO for the particular aircraft gives instructions on the storage of jack pads.

4-15. **Use of Jacks.** Placing the jack under the aircraft is an important operation which should not be done haphazardly. Figure 15 shows how the jacks should be positioned. You should also know the capacity called for in the aircraft TO and the capacity of the jacks on hand. If you have the proper jacks, again check the TO on how to place them under the aircraft. You will need to know how to place the jack under the wing to obtain greatest support with least danger of slipping. Now let's discuss a few general jacking hints.

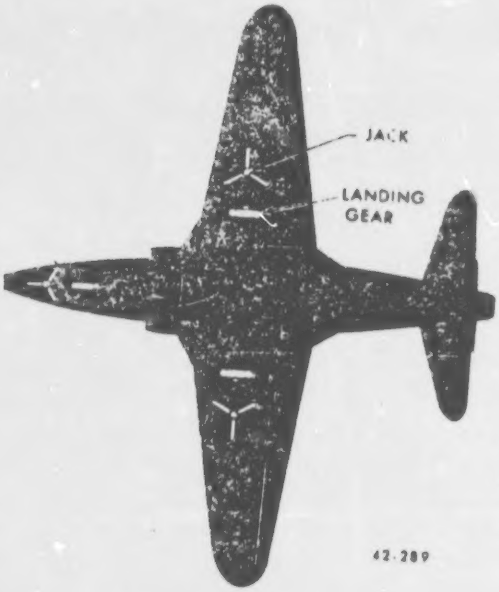


Figure 15. Jack placement under aircraft.

4-16. Figure 15 shows wing jacks arranged so that the two inside legs run parallel to the fuselage. The nose jack is placed so that its inside legs run perpendicular to the fuselage. This increases stability. The positioning of the legs is the major item to consider, but another item is the positioning of the wheels. You should locate the legs with wheels in a certain manner. Make it easy to get the jack from beneath the aircraft quickly as soon as the load is removed from it. Why hurry? Because you will probably be lowering the aircraft onto its landing gears. Shock struts will often bind a little and not compress to their normal position at once when lowered. They may drop suddenly or possibly hang up until you shake the wingtip a bit. If this should happen, you can see that it would be very easy for the wing to become impaled on the jack. Therefore, the best procedure is to align the legs properly. Have the wheels pointed in the direction you intend to move the jack when it is free. This may not be the way you would do it when working on a smooth floor. It may be just as easy to slide the jack out as it would be to tilt it over and roll it. If this is the case, don't worry about the wheels. However, a crack in the floor or any other rough spot may make rolling necessary.

4-17. After the jacks have been properly placed, remove the wheel chocks. Then run the screw extension up to the jack pad. Never tilt the jack to line it up with the aircraft jack pad; instead slide it over. Now open the reservoir air vent, close the needle valve, and start pumping.

4-18. When jacking aircraft, be sure to raise all jacks simultaneously. The best way to do this is to have four men performing the operation: one man on each jack and one "point man" who stands out in front of the aircraft giving directions. If four men are not available, three men can do it with caution. Some bases even authorize two men to jack an aircraft. They do it by raising the main gears a little and then raising the nose gear a little, etc. But, this is not advised if you have three men, because it is better to keep the aircraft level.

4-19. The raising and lowering of large aircraft sometimes require the use of more than one jack under each wing. In fact, as many as three jacks under each wing may be required when raising our heaviest bombers. In this case, a hydraulic jacking manifold (MA-1 cart) would likely [illegible]. The hydraulic jacking manifold is a portable unit with pressure lines going to each jack. It provides equal hydraulic pressure to all of the jacks. The manifold pressure for right-or left- wing jacks is controlled by shutoff valves on the MA-1 cart. This allows the aircraft to be jacked evenly.

4-20. One word of caution regarding the use of any jack. Always read the applicable TOs before begining any jacking operation.

4-21. **Inspection and Maintenance of Jacks.** Proper inspection and maintenance of hydraulic jacks help prevent mechanical or hydraulic failure of jacks. In turn, this prevents possible injury to maintenance personnel. You, the hydraulic repairman, may have the responibility of performing these inspections and maintenance tasks. The technical order pertaining to the particular jack tells you how to do the inspections and maintenance. However, there are some general procedures that pertain to all jacks. For example, before you use the jack, you should check the base or tripod for looseness. The hand pump should be checked for proper operation. Along with this check, you should look for any hydraulic leaks that may have developed. Inspect the ram for evidence of any burrs or damage. The outer surface and the grooves of the ram must be kept clean. The locknut should rotate freely around the ram with such ease that it will move downward by its own weight.

4-22. At least once a week, the reservoir fluid level should be checked. Thr fluid level should be just below the filler opening. The reservoir should be drained and flushed with kerosene (or as approbed solvent) at least once every 3 months. Occasionally, the pump handle pivots and dolly wheels should be lubricated with a light lubricating oil.

4-23. When jacks are not in use, they should be stored upright and in a dry place. The ram should be completely retracted down into the cylinder. This prevents dirt and grit from accumulating on the outer surfaces and grooves of the ram.

5. Maintenance Stands

5-1. Closely associated with hydraulically operated aircraft jacks are hydraulically operated maintenance stands. There are several types of these stands. The elevating mechanism on all is basically the same as on hydraulic jacks. We shall discuss one of these stands: the B-1 maintenance stand.

5-2. The B-1 maintenance stand is shown in figure 16. It is a hydraulically operated combination of stair structure and work platform. The platform can be raised and held at any position between 3 and 10 feet. This is done by a hydraulic cylinder hand pump. Stair support members and stair handrails are rigged, making the platform self-aligning and level. Because of the handrails on both the stairs and the work platform, the stand is quite safe.

5-3. Another 4 feet can be added to the height of the B-1 platform. This is done by placing a C-1 stand, shown in figure 17, into the platform post sockets. The post sockets provide for either the attachment of platform handrails or the C-1 stand.

5-4. The base of the stand, made of welded tubular steel, is 11 feet long and 4 feet wide. A cylindrical hydraulic fluid reservoir is welded across the width of the frame. The platform lifting mechanism is a hydraulic cylinder assembly. It is actuated by a hydraulic hand pump

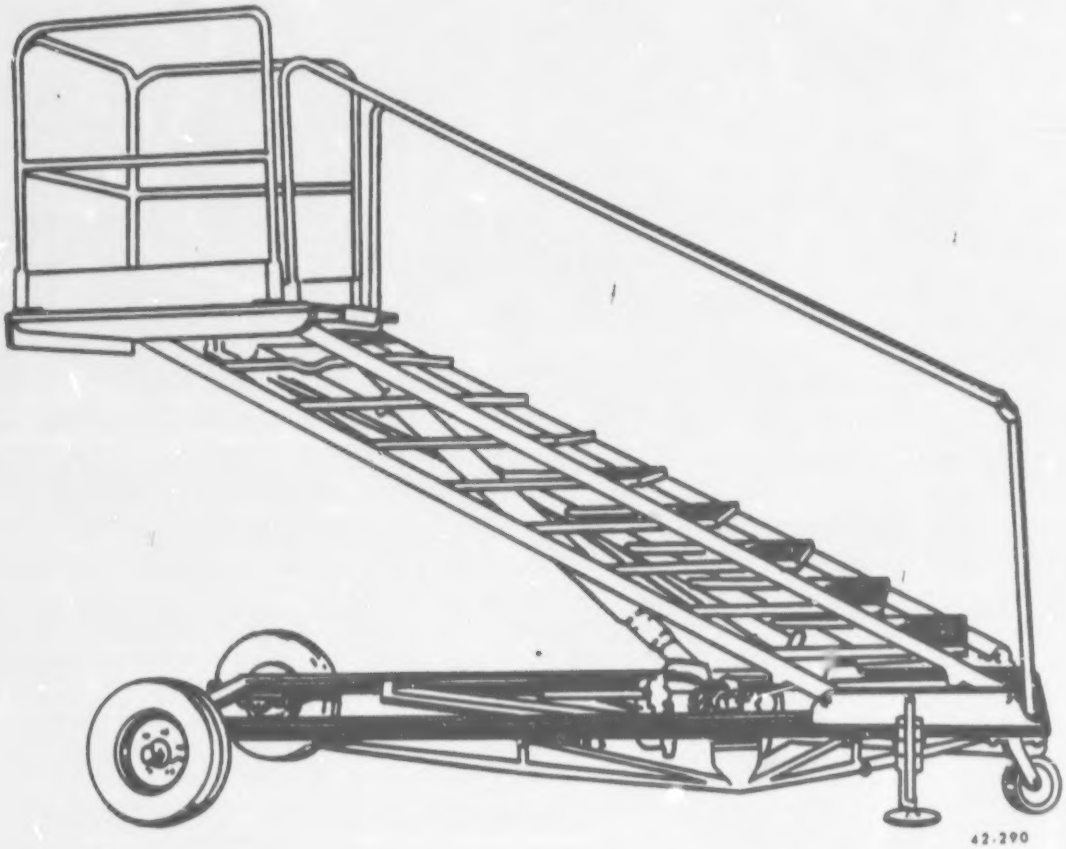


Figure 16. B-1 maintenance stand.

also mounted on the base. The hydraulic cylinder assembly connects the base to the upper structure to give lift. It also gives support to the upper structure to give lift. It also gives support to the stairs and platform in all raised positions of the platform.

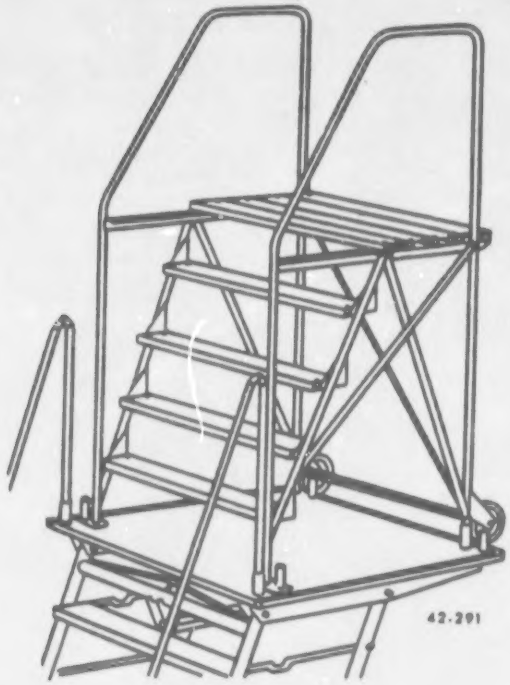


Figure 17. C-1 stand mounted on a B-1 platform.

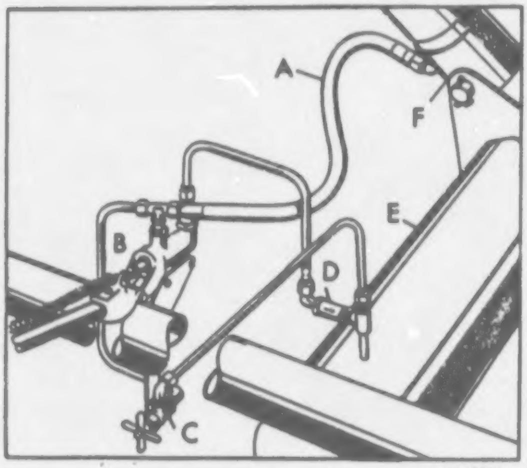
5-5. **Undercarriage Equipment.** The B-1 maintenance stand has a tow bar bolted to the front of the frame and wheels at each corner. the two front wheels are swivel-castered. The two rear wheels are 16-inch, pneumatic-tired steel wheels.

5-6. Two base locks are bolted to the forward end of the frame to prevent movement of the stand during use. They give stability to the stand when the platform is extended. The locks are spring-loaded, vertical steel stems equipped with foot plates. When the foot pedal is pressed downward, the plates sit on the floot. In the down position the locks tend to relieve the weight resting on the casters and prevent their movement.

5-7. **Hydraulic System.** The hydraulic cylinder holds the platform at the desired height. To prevent accidental lowering of the cylinder, a safety lock is used. The lock is a U-shaped steel device. Designed to fit into grooves cut into the cylinder assembly with a length of chain. This prevents its being lost or otherwise separated from the maintenance stand. It should be installed before you ascend the stairs to the platform.

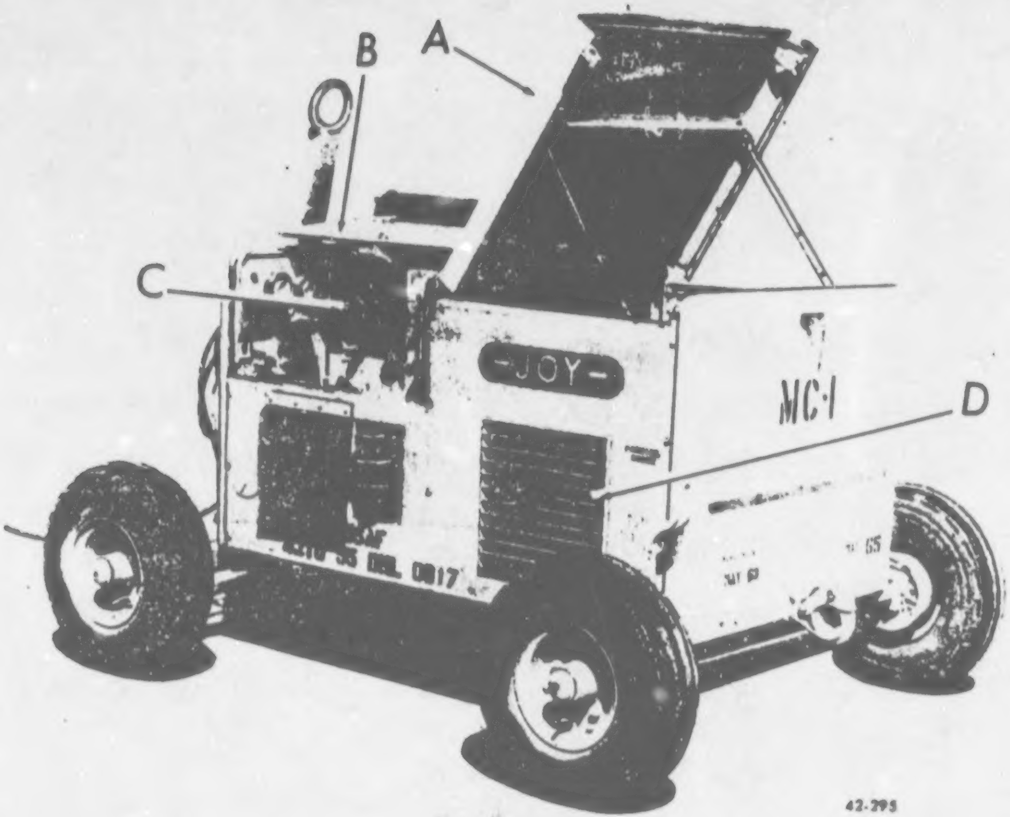
5-8. The hydraulic system shown in figure 18 functions to supply fluid under pressure to the cylinder assembly. Hydraulic fluid from the handpump (B) goes through the hose (A) to the lower end of the cylinder (F). Pumping the hand pump causes the cylinder assembly to extend. The bypass valve (C), when in the closed position, traps the hydraulic fluid pressure in the cylinder. When the bypass valve is opened, fluid in the cylinder bypasses the hand pump and returns to the reservoir (E). This causes the cylinder to retract. The speed of retraction is controlled by the amount of bypass valve opening. The suction part of the hand pump has a protective strainer (D). This strainer prevents particles from entering the pump.

5-9. **Stair and Platform Assemblies.** The stair support assembly consists of two oblong box sections made of welded steel tubing. These two sections are attached by pivot pins to the base assembly at the bottom. The platform is also attached to these suctions by pivot pins. The stairs are mounted between these two sections. They remain parallel to the base at all platform levels. The stair handrail and posts are hinged at both connections at the top. This keeps the handrails parallel to the stair support frames at all times.



A. Connecting hose
B. Hand pump
C. Bypass valve
D. Strainer
E. Reservoir
F. Cylinder assembly

Figure 18. B-1 stand hydraulic system.



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A. Hood
B. Instrument panel cover
C. Instrument panel
D. Automatic shutters

Figure 19. MC-1 air compressor.

5-10. The work platform is mounted on the upper structure of the stair support assembly. It is approximately 4 feet square. It is made of 1-inch plywood and covered with dimpled sheet-metal panels. The platform is bolted to the upper structure and supported by steel channels. This enables it to sustain a static load of 1500 pounds. However, the platform *should never be raised when it is carrying a load greater than 500 pounds.*

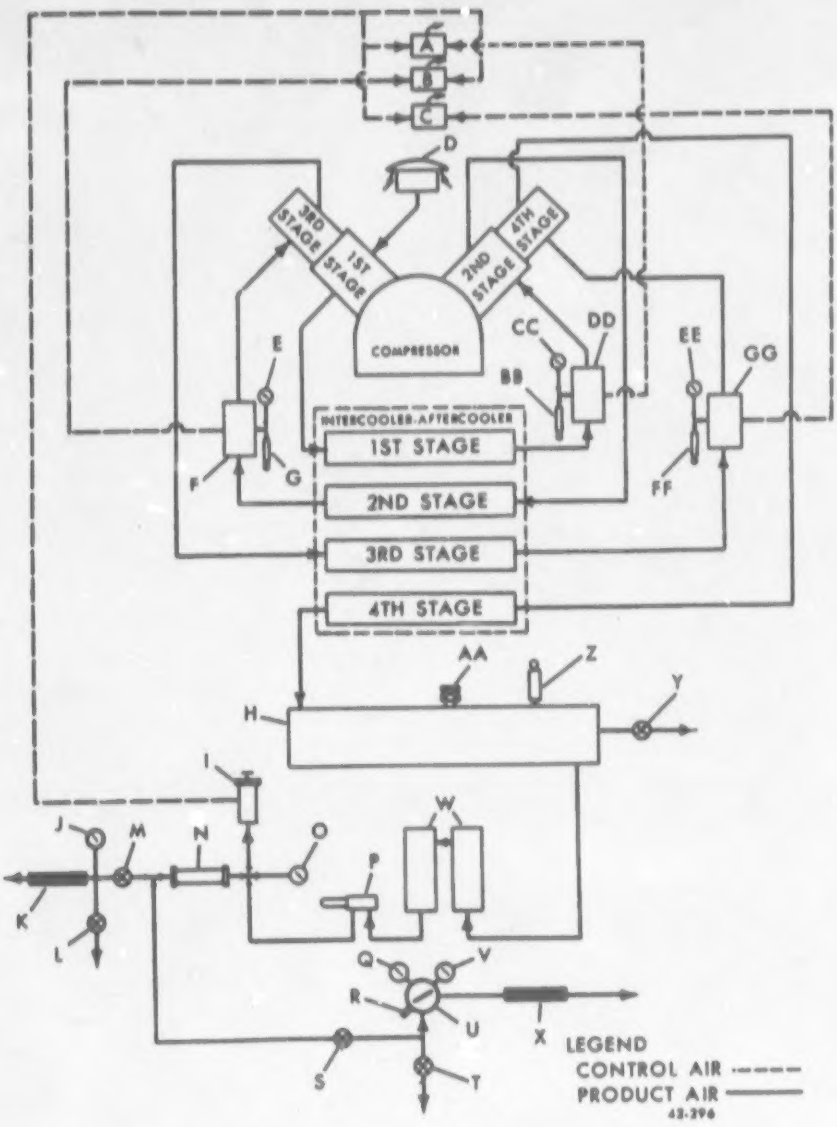
5-11. The B-1 maintenance stand requires periodic inspections and servicing to insure safe and dependable service. Comply with TO procedures if you want good operation of this equipment.

6. Portable Air Compressors

6-1. Another type of ground-support equipment which you will use is the portable air compressor. It is used to charge pneumatic system air bottles, shock struts, accumulators, tires and for several other purposes as well. There are various types and sizes of compressors in use by the Air Force. The choice of compressor is based on the work requirements and work area facilities. Many shops have a "house air" system, but a portable compressor is needed for flight line work. We will discuss one representative type.

6-2. An air compressor in general use on the flight line is the MC-1 (Joy) air compressor, shown in figure 19. This compressor can be used for charging high-pressure pneumatic systems and to service tires on portable equipment.

6-3. The MC-1 air compressor is designed for continuous operation. It has a rated capacity of 15 cubic feet per minute (cfm) of free air compressed to 3500 psi. Notice in figure 19 that the compressor is a completely self-contained unit mounted on a four-wheel


A
B
C
D
3RD STAGE
1ST STAGE
2ND STAGE
4TH STAGE
COMPRESSOR
E
CC
DD
BB
EE
GG
INTERCOOLER-AFTERCOOLER
1ST STAGE
2ND STAGE
3RD STAGE
4TH STAGE
F
G
FF
AA
Z
Y
H
I
J
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N
O
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K
L
Q
V
R
U
X
S
T
LEGEND
CONTROL AIR ----
PRODUCT AIR ——
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Figure 20. MC-1 flow schematic.

A. First-stage blowdown valve
B. Second-stage blowdown valve
C. Third-stage blowdown valve
D. Air cleaner
E. Second-stage pressure gage
F. Second-stage condensate chamber
G. 275 psi pressure relief valve
H. Air receiver
I. Pilot valve
J. High-pressure service line pressure gage
K. High-pressure servicing hose
L. High-pressure service line relief valve
M. High-pressure service line shut-off valve
N. Priority valve (2400 psi)
O. Receiver pressure gage
P. High-pressure air filter
Q. Regulator-outlet pressure gage
R. 600 psi safety valve
S. Low-pressure service line shut-off valve.
T. Low-pressure service line relief valve
U. Pressure regulator
V. Regulator inlet pressure gage
W. Dehydrators
X. Low-pressure servicing hose
Y. Receiver drain valve
Z. 3800-psi pressure relief valve
AA. Safety head (pop-off valve)
BB. 75-psi pressure relief valve
CC. First-stage pressure gage
DD. First-stage condensate chamber
EE. Third-stage pressure gage
FF. 1100-psi pressure relief valve
GG. Third-stage condensate chamber

chassis. It consists of the following main components and systems: air compressor assembly, engine assembly, instrument panel, dehydrator installation, inclosure, chassis, compressor control system, electrical system, high-pressure servicing system, and the low-pressure service system.

6-4. The air compressor assembly is mounted on the chassis at the rear of the inclosure (tow-bar-end being the front). The compressor is a four-stage, air-cooled, V-type, single-acting, reciprocating unit. Two cylinders occupy each wing of the V: the first and third stages in one, and the second and fourth stages in the other. Two pistons operate in tandem, one above the other, (see fig. 20) using the same connecting rod. The air compressed in four separate stages. The sizes of the pistons and cylinders get smaller with each stage of compression.

6-5. The compressor is driven by a four-cylinder gasoline engine which runs at a governed speed of 2200 rpm. A clutch takeoff assembly is bolted to the engine crankcase. It permits starting and operating the engine without load. It is engaged by a clutch lever which protrudes through the housing and instrument panel.

6-6. The instruments and manually operated controls are located on the instrument panel (C) (fig. 19). The only exceptions are the parking brake lever and carburetor priming lever. The instrument panel will be discussed in detail in a following paragraph.

6-7. A diaphragm-valve-type low-pressure regulator adjusts the service line pressure from 0 to 500 psi. Two gages are mounted on the regulator: one gage shows the pressure in the air receiver and the other the pressure at the service line.

6-8. The dehydrator and air filter installation includes the high-pressure air filter, two oxygen purifier cylinders, and interconnecting tubing. The installation is secured to the chassis in front of the instrument panel. The two oxygen purifier cylinders are connected in series between the air receiver and high-pressure filter. (An oxygen purifier cylinder is merely a dehydrator cylinder.) Each cylinder contains a nonreactivating oxygen purifier cartridge. It absorbs the water vapor from the air that was not removed by the condensation chambers.

6-9. The air compressor inclosure provides all-weather protection for the operating components. Two covers (A) and (B) protect the engine and instrument panel. The ventilating shutter (D) is automatic, thermostatically controlled. It maintains suitable temperature conditions around the components.

6-10. The MC-1s electrical system provides power for starting the engine and for operating the hourmeter. The hourmeter, mounted on the instrument panel, is started and stopped by a pressure switch. It runs only when the compressor is compressing air.

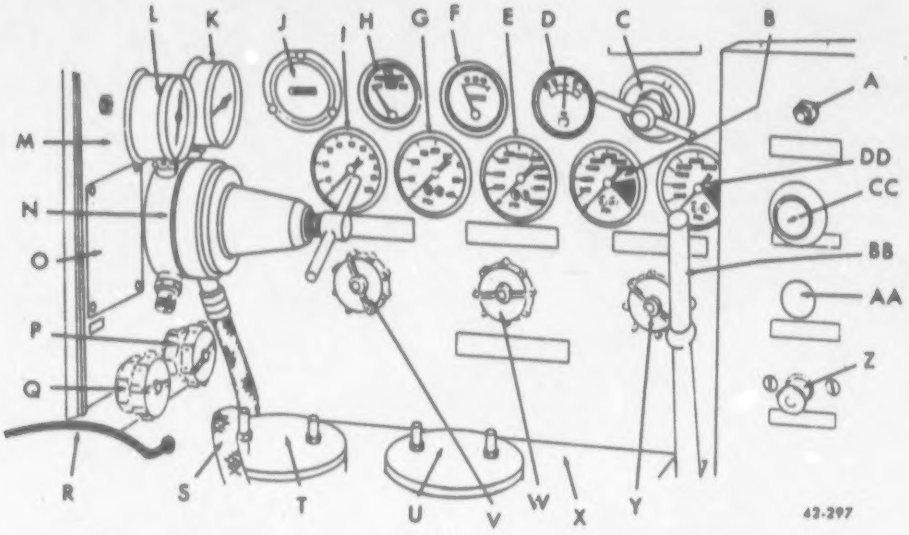
6-11. This completes our general discussion of the MC-1 compressor. Let's discuss the schematic flow diagram of the compressor assembly. It will give us a better idea of how each component ties into the overall operation.

6-12. **Schematic Flow Diagram.** Figure 20 illustrates the flow schematic diagram. While studying this schematic, you will find that some callouts are not mentioned in this text. However, this applies only to callouts which are self-explanatory in the figure legend.

6-13. The first section of the flow diagram we will discuss is the compressor control system. It controls the compression of air by the compressor and removes moisture collected in the condensation chambers (F, DD, and GG). The control system consists mainly of the pilot valve (I) and the blowdown valves (A, B, and C), plus the interconnecting tubing. The pilot valve controls the flow of air from the air receiver (H) to the blowdown valves. The pilot valve can be hand adjusted so that receiver air flows through it at all times. In addition, it can also be set for automatic operation. When on automatic, it opens when the pressure in the air receiver reaches 3500 psi. The pressures at which the pilot valve automatically opens and closes are known as the "unload" and "load" pressures. The three blowdown valves provide a means of venting the four compressor stages to the atmosphere. When the pilot valve opens, the three blowdown valves also open. This prevents the compression of air because the first three stages are vented to air. In addition, the moisture accumulated in the condensate chambers is blown out. When the pilot valve closes, the blowdown valves likewise close, permitting the compressor to compress air.

6-14. The high-pressure servicing system provides a source of compressed air in the range of 2400 to 3500 psi. This system consists of the high-pressure servicing hose (K), service line relief valve (L), service line shutoff valve (M), 2400-psi priority valve (N), dehydrators (W), air filter (P), and 500-cubic-inch air receiver (H).

6-15. The low-pressure system provides a source of compressed air at pressures in the range of 0 to 500 psi. This system consists of a hose (X), low-pressure chuck (not shown), low-pressure regulator (U), and shutoff valve (S). Also included are the low-pressure service line relief valve (T), a safety valve (R), dehydrators



A. Ignition switch
B. Air receiver pressure gage
C. Pilot valve
D. Ammeter
E. Third-stage pressure gage
F. Compressor oil pressure gage
G. Second-stage pressure gage
H. Engine oil pressure indicator
I. First-stage pressure gage
J. Hourmeter
K. Regulator inlet pressure gage
L. Regulator outlet pressure gage
M. Control panel
N. Low-pressure regulator
O. Instruction plate
P. Low-pressure servicing line shut-off valve
Q. Low-pressure servicing relief valve
R. High-pressure servicing hose
S. Low-pressure servicing hose
T. No. 1 dehydrator
U. No. 2 dehydrator
V. High-pressure servicing line relief valve
W. High-pressure servicing line shut-off valve
X. Tool and technical manual box
Y. Air receiver drain valve
Z. Starter switch
AA. Choke control
BB. Clutch lever
CC. Engine speed regulator
DD. High-pressure service line pressure gage

Figure 21. MC-1 instrument panel.

(W), air filter (P), and of course the 500-cubic inch air receiver. CAUTION: *The low-pressure chuck attached to the end of the servicing hose is for pressure from 0 to 300 psi only.*

6-16. You should now have an understanding of the systems making up the compressor assembly. Let's study the unit further by discussing how it is operated. Keep in mind that as you study each step in its operation, you should refer to figure 20 often. This will help you to better understand the overall operation of the air flow systems.

6-17. **Operation.** The operation of the MC-1 compressor is relatively simple. However, like other aerospace ground equipment, there are definit procedures that must be followed. The first thing you should always do is check the AFTO Form 45 for the status of the unit. Then perform a visual inspection of the entire unit. Of course the instrument panel door and compressor hood (items B and A in fig. 19) must be open to perform this inspection. Now check the engine oil, compressor oil, fuel, and battery for proper levels. Also check the engine air cleaner and compressor air cleaner. If you find the unit serviceable, you are ready to proceed with the starting operation.

6-18. Refer to the instrument panel shown in figure 21 for the following discussion. First disengage the clutch by moving the clutch lever (BB) towards the instrument panel. Then close the servicing line shutoff valves (P and W). Then close the servicing line relief valves (Q and V). Next, make certain that the pilot valve (C) is in the manual unload position. This will take the load off the compressor when it is started. Turning the handle clockwise until the valve spring tension can first be felt will position the pilot valve to manual. From this point, turn the handle approximately one full turn more (still clockwise). Now, close the air receiver drain valve (Y). Next, close the low-pressure regulator (N) by turning the handle counterclockwise until all spring tension is relieved. Finally, if the temperature is below freezing, close the compressor hood. WARNING: *Never start the engine in an inclosed space without venting the exhaust gases to the outside atmosphere.*

6-19. To start the engine, you first pull the choke control (AA) part way out. The amount of choking required depends on both the engine temperature and the ambient temperature. Next, push the ignition switch (A) all the way in. Then press the starter switch (Z) and allow the starter to crank the engine until it starts. It is important that you do not hold the switch in for more than 30 seconds. Prolonged cranking will cause overheating of the starter. After starting, observe the engine oil pressure indicator (H) and ammeter (D). (If there is no oil pressure indication within 30 seconds, pull the ignition switch.) Allow the oil pressure to stabilize. Then operate the engine at idling speed until warmed up to the normal operating temperature. When the engine is warmed (operating smoothly at idling speed without choking), pull the engine speed regulator (CC) part way out. NOTE: Now is a good time to double check and make certain that valves P, Q, V, W, and Y are closed.

6-20. Now you are ready to engage the clutch. You do this by moving the lever (BB) away from the instrument panel. Then check the compressor oil pressure gage (F). If there is no indication of pressure within 30 seconds, disengage the clutch. When the oil pressure is stabilized, pull the engine speed regulator knob out as far as possible. This gives you maximum governed engine speed. Lock the control in that position by rotating it clockwise one-fourth turn. Next manually load the compressor by turning the handle of the pilot valve (C) two full turns counterclockwise. This sets the pilot valve to automatically load and unload the compressor. Now observe all of the interstage pressure gages (I, G, and E). These gages should almost immediately indicate a gradually increasing pressure. When the air receiver pressure gage (B) reaches maximum, the normal pressure for the first stage (I) is 45 to 55 psi, the second stage (G) is 190 to 230 psi, and the third stage (E) is 875 to 1000 psi.

6-21. To use the high-pressure system, connect the high-pressure service line (R) to the system that you are servicing. Use only a high-pressure chuck. Then open the high-pressure service line shutoff valve (W) and service to the required psi. The pressure reading will show on the high-pressure service line gage (DD).

6-22. If you have to service a tire or some other low-pressure unit (below 300 psi), use the low-pressure system. To use this system, open the low-pressure servicing line shutoff valve (P). At the same time, make sure that a low-pressure chuck is attached to the low-pressure servicing line (S). While watching the outlet pressure gage (L), adjust the low-pressure regulator (N) to the desired psi. You are now ready to service the tire or unit.

6-23. After servicing with either high or low pressure, close the servicing line shutoff valve (W or P). Then open the respective service line relief valve (V or Q) to discharge the pressure trapped in the service lines. Items J, K, M, O, T, and U are self-explanatory.

6-24. To shut down the compressor, you should first manually unload the air compressor with the pilot valve (C). Turn the handle clockwise until the valve spring tension can first be felt. From this point, turn the handle approximately one full turn clockwise. Next, adjust the engine speed regulator (CC) to a fast idle and allow it to run until the compressor cools down. After this, disengage the clutch and allow the engine to idle for 3 to 5 minutes. When the engine has cooled down, pull the ignition switch to stop the engine. If the compressor is not on a standby status (may be used again soon), drain the air receiver by opening the drain valve (Y). After sufficient cooling, you may close the hood and panel doors.

6-25. An air compressor is needed almost daily in your job. To make your work easier and to make your compressor last longer, observe the following rules:

- Never start the engine with the clutch engaged.
- Never start the engine with the clutch engaged.
- Never engage the clutch when the engine is operating at speeds faster than fast idle.
- Never engage the clutch when the compressor controls are in the load position.
- Never tighten the service line relief and shutoff valves or receiver drain valve to exceed 35 inch-pounds. These valves are constructed with an internal ball and spring assembly. Thus, you do not have to exert a great force to shut them off.

6-26. **Operator's Maintenance.** Operator's maintenance consists of visually inspecting the unit, checking oil levels, and servicing if required. Minor maintenance such as servicing a low tire and tightening loose screws, nuts, and bolts are also done by the user. Major maintenance such as inspections and engine or compressor troubles are done by ground power personnel. However, you may be required to help ground power people troubleshoot the compressor when difficult problems arise. More in-

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formation for repair may be found in TOs covering your unit.

6-27. Remember to practice your general safety precautions while using compressed air. For example, a loose hose discharging high-pressure air is more dangerous than a whip. Always release the pressure in the servicing line before disconnecting it. *And, never, never engage in horseplay with pressurized air*

7. Ultrasonic Filter Cleaning

7-1. Sound is vibrational energy. Vibrations at a frequency of 16 to 15,000 cycles per second can be heard by the human ear. Vibrations above this level are termed ultrasonic. One of the first practical uses of ultrasonics was a sonar device. This was developed during World War I for detection of submarines.

7-2. As research continued, it was found that ultrasonic energy could be used for mixing "unmixable" liquids, destroying bacteria, acceleration of chemical reactions, cleaning intricate mechanisms, and many other uses. This is where we come into the picture. We use ultrasonics for cleaning intricate mechanisms such as filters.

7-3. Ultrasonic cleaners are designed for many different applications. They range in size from a small table top unit up to 500-gallon cleaners, or possibly larger. They can be used for cleaning filters, electronic parts, and small or large mechanical units. Possibly you have taken your wristwatch to a jeweler for cleaning; many jewelers use ultrasonic cleaners to clean watches.

7-4. **The Sonic System.** A sonic system is composed of two basic parts: a generator and a transducer. The generator supplies alternating electrical energy to the transducer. The generator may be either electronic or rotary. The transducer converts electrical energy into mechanical energy in the form of vibrations. The transducer is the heart of the sonic system, so we will cover it in more detail.

7-5. Transducers fall into two classes—piezoelectric and magnetrostrictive. A piezoelectric transducer is composed of a natural crystal such as quartz. Or, it can be a special ceramic. They both emit sonic vibrations while under the influence of an electrical voltage. The magnetrostrictive transducer is composed of a metal such as cobalt, nickel, or iron. A magnetrostrictive metal is one which undergoes size change when subjected to a magnetic field. When the magnetic field is relieved, the metal returns to its natural dimensions. In a magnetrostrictive sonic system, the transducer can then be vibrated by an interrupted or alternating magnetic field.

7-6. The choice of a transducer depends upon the sonic energy application needed. Generally speaking, the crystal or ceramic transducers are used for low power applications. The magnetrostrictive transducer is used where power is to be applied for longer periods of time without loss in efficiency.

7-7. **Sonic Energy Cleaning.** Ultrasonic cleaning accomplishes its purpose in two ways. One, cavitation of the liquid, is physical. The other is chemical—the solution dissolving the soluble soilage. For this we use a tank filled with a cleaning solution. The type of solution depends on the type of soils to be dissolved. We attach a transducer to the bottom of the tank to produce vibrations. These are transmitted throughout the cleaning solution and cause the cavitation effect.

7-8. Cavitation is the formation of billions of microscopic sized cavities within a liquid. These cavities are filled with vaporized solution. They are caused when the pressure on the liquid is reduced below the vapor pressure point of the liquid. Under this condition the vapor bubbles or cavities appear throughout the liquid in a flash.

7-9. How is this low pressure created? When sound waves are transmitted through air, there are alternating zones of high pressure and low pressure. The air molecules are squeezed together during the high-pressure front of the wave. But, they are spread apart during the low-pressure part. When sound waves pass through a liquid, it is almost impossible to squeeze the liquid molecules together. But, a low-pressure area follows the high-pressure front. Now, the low vapor pressure (the tendency of all liquids to vaporize in a vacuum) will cause the liquid molecules to separate from each other. At this point they are no longer a liquid but enter the gaseous state. This forms billions of vapor cavities in the low-pressure front of the sound wave. Now comes the high-pressure front of the next wave. It pressurizes all the vapor in the cavities, compresses the vapor-liquid mixture. It collapses all the cavities by compressing the vapor back into a liquid. Collapse of these cavities is called implosion.

7-10. While the energy in any one implosion is extremely small, there is an uncountable number of them. It is calculated that enormous pressures (in the order of 10,000 pounds per square inch) and enormous temperatures (of approximately 20,000° F.) are developed. The formation and bursting of these vapor pockets with their fantastic pressures and temperatures does the scrubbing. This action takes place millions of times per minute. It can be described as "millions of tiny scrubbing fingers at work." The sound waves are simply the mechanical means to achieve cavitation.

7-11. Dissolved air and other gases play a role in ultrasonic cleaning. Some of the sound wave energy is absorbed by the cushioning effect of the air bubbles in the solvent. Fortunately, the sound waves cause the air bubbles to coalesce (join together) and float to the surface, where they escape. Ultrasonic agitation will outgas (cause gas to leave) liquids within a period of 30 seconds to a few minutes. During this time the trapped air bubbles act as an energy sink. Cleaning will not be very effective until the liquid is completely outgassed.

7-12. **PD SANE 50 Ultrasonic Cleaner.** The SANE 50 is a typical machine for discussion of specific ultrasonic cleaners. This cleaning machine rapidly cleans and tests woven wire filter elements. Cleaning solutions used with this machine are carbon remover, Fed. Spec. P-C-111A, and trichloroethylene, Fed. Spec. O-T-634A.

WARNING: Carbon remover and trichloroethylene are toxic. Handle carefully to avoid breathing the vapors and to prevent contact with exposed skin areas. Protective clothing including eyeshields, rubber safety-toe shoes, plastic-covered aprons, and rubber-impregnated gloves will be worn by personnel working with these solutions.

7-13. The SANE 50 ultrasonic cleaner is shown in figure 22. It consists primarily of five tanks, four filters, and two control panels (A and E). The tanks are presoak (D), boil (F), cleaning (G), condensate (H), and test tank (I). Each of these tanks serves a separate function in the cleaning process.

7-14. *Presoak tank.* The presoak tank (D) is filled with carbon remover. It has a cooling coil, heater, thermostat, drain pump, and sonic unit. This tank is used for loosening the dirt in the filter elements.

7-15. *Boil tank.* The boil tank (F) is filled with trichloroethylene and is provided with a heater and thermostat. This tank was at first used to dissolve the carbon remover and dirt loosened during the presoak operation. Recently, there has been a change in procedures for cleaning wire mesh filter elements. The filters being cleaned bypass the boil tank. They go from the presoak tank directly to the cleaning tank. The boil tank heats and vaporizes the dirty trichloroethylene for recovery in the condenser.

7-16. *Cleaning tank.* The cleaning tank (G) is also filled with trichloroethylene. This tank is provided with a cooling coil, thermostat, sonic unit, three filters (C) (50-, 10-, and 3-micron), pump, and drain valve. The cleaning tank provides ultrasonic agitation and circulation of the cleaning fluid. This further removes dirt particles from the filters being cleaned. The circulation passes the dirt on to the filters within the stand.

7-17. *Condensate tank.* The condensate tank (H) is kept full of trichloroethylene by the normal boil-condense cycle of the unit. This is done by the use of a condensing coil, collecting trough, and water separator. The condensing coil prevents vapors from rising above a safe level in the center bay. The trough, located just below the condensing coil, is slanted toward the water separator. The condensed liquid flows down the trough to the water separator. Trichloroethylene, being heavier than water, settles to the bottom and goes into the condensate tank. Water rises to the top of the separator and is drained overboard. The condensate tank stores trichloroethylene for servicing the test tank.

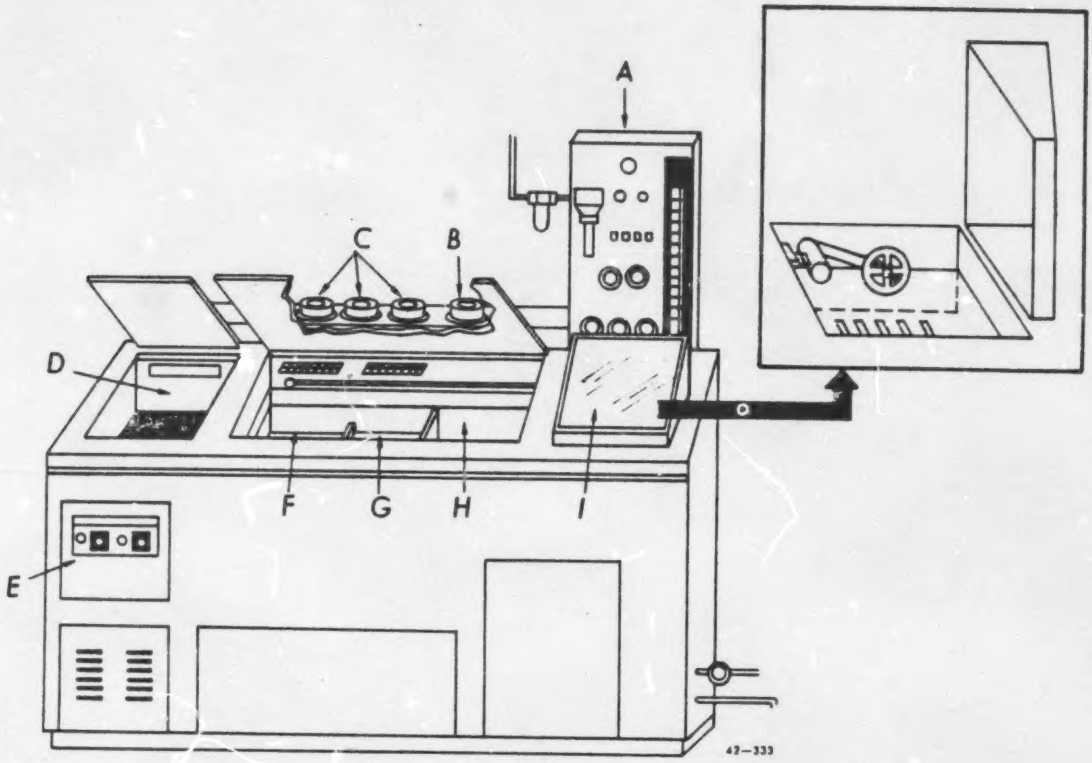
7-18. *Test tank.* The test tank (I) is used to test cleaned filter elements for internal damage. The tank is filled with trichloroethylene from the condensate tank. It has a 3-micron filter (B) and pump for servicing and cleaning the test fluid. A cooling coil, heater, and thermostat switch control the test temperature. The test tank has a fixture for mounting and supplying air pressure to the element being tested.

7-19. **Cleaning Woven Wire Filter Elements.** Before cleaning, the filter elements are inspected for obvious damage beyond economical repair. Total repair may not exceed 3 percent of the filter element's total wire cloth area. Remove the O-ring seals from the elements selected for cleaning.

7-20. To start the cleaning process, suspend the elements in the presoak tank (D). This tank is filled with carbon remover. With the temperature at 100° F, ultrasonically agitate the elements for 15 minutes. Remove the elements and allow to drain.

7-21. After draining, suspend the elements in the ultrasonic cleaning tank (G). The cleaning tank is filled with trichloroethylene at a temperature of 140° to 150 ° F. Ultrasonically agitate for 10 to 30 minutes. The longer period of time is required when six or more elements are cleaned at the same time.

7-22. While the elements are in the cleaning tank, recirculate the cleaning fluid through the filters (C) for 5 minutes. Then, again agitate the elements for 3 minutes. Immediately take a 300-milliliter (1/2-cup) sample of the cleaning fluid. Filter this sample through a 5.0-micron membrane filter patch. Visually inspect the filter patch for solid particles or discoloration from solids. Elements that are not clean (as in-



A. Control and test panel
B. Test tank filter
C. Cleaning tank filters (3)
D. Presoak tank
E. Sonic control panel (presoak and cleaning tanks)
F. Boil tank
G. Cleaning tank
H. Condensate tank
I. Test tank

Figure 22. Ultrasonic filter cleaner.

dicated by the dirty filter patch) must be reprocessed until cleanliness is assured.

7-23. **Bubble Test with Trichloroethylene.** All cleaned filter elements must be tested for serviceability. This is done in the test tank (I). The element is attached to the test fixture and air pressure is applied inside the element. The fluid level (trichloroethylene) should be 1/2 inch above the element for this test. Apply the specified air pressure as measured on the manometer and rotate the element. Air should escape through the pores of the element at a uniform rate over the entire surface. During this process a specified back pressure must be indicated on the manometer. Minimum back pressures to be maintained in the manometer while air is escaping through the filter are:

20 in. of H_2O for a 15-micron absolute element.

12 in. of H_2O for a 25-micron absolute element.

7.5 in. of H_2O for a 40-micron absolute element.

(The absolute rating indicates nothing larger will pass through it.)

Failure to maintain these back pressures indicates enlarged pores or a ruptured element. In this case the filter is condemned if the damaged area exceeds 3 percent of the total surface area. It may be repaired if the damage is less than 3 percent.

7-24. A large amount or a steady stream of bubbles coming from one spot on the element points up a fault. This is an indication of high porosity or a rupture at that point. If this occurs and the element fails the minimum back pressure test, reduce the air pressure to zero. Then gradually increase the pressure until the first continuous stream of bubbles occurs. If this bubble point falls between 3 in. of H_2O and the minimum allowed, the element is reparable. Elements testing less than 3 in. of H_2O are condemned. The point on the wire cloth needing repair must be marked with a red pencil during the bubble test.

7-25. Use caution to prevent the filtering surface from being contaminated by handling. After testing, package the dry serviceable elements in individual clean plastic bags.

7-26. **Repair of Woven Wire Filter Elements.** The following equipment and materials are required for element repair: (1) epoxy resin, (2) catalyst, (3) syringe (2-cc), (4) hypodermic needle (21-gage), and (5) oven (1000 watts).

7-27. Repair is made by mixing catalyst and resin. The ratio for mixing is 8 parts catalyst per 100 parts resin, mixed thoroughly. The usable life ("pot life") of the mixed epoxy resin is 20 to 30 minutes. Therefore, it should be used as soon as possible after mixing. Draw approximately 1/2 cc of mixed epoxy resin into a syrings with the needle removed. Replace the needle and inject small quantities of the mixture directly into the area requiring repair. Press the epoxy resin into the pores of the wire cloth to assure a satisfactory bond. The purpose is to seal the defective area. Use care in keeping the repair area to a minimum.

7-28. Use epoxy resin in a well-ventilated room and wear gloves or protective hand cream. Clean the hypodermic needle and syringe in methylethylketone before the epoxy resin hardens.

7-29. Place the repair element in an oven at 60° C. (140° F.) and cure for 30 minutes. Allow the element to cool to room temperature and repeat the bubble test. Additional repair may be necessary if the minimum bubble point is not attained. However, if more than 3 percent of the area is affected by the total repair, discard the element.

7-30. Always use the latest appropriate technical orders when operating equipment or making repairs. As technical advances are made, methods and procedures are subject to change.

7-31. Throughout this chapter we have talked about equipment which is designed primarily for use with aircraft. However, there are many other types of pneudraulic equipment used by the Air Force. For instance, staff cars may have hydraulic power steering and brakes. Snowplows, bulldozers, fire trucks, tractors, lifts, crane hoists, etc., may incorporate some sort of hydraulic system. Equipment of this sort is normally assigned to the motor vehicle section for maintenance. Sometimes, however, you may be called on to assist with a tough problem that arises in their systems. A trained hydraulic man need only study the diagram of a system to determine the path of fluid flow and the operation. For this reason, it isn't necessary to cover each piece of equipment you may run across.

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CHAPTER 2

Use of Hydraulic Schematics

TO PROPERLY troubleshoot hydraulic systems, it is necessary for you to know how to read and use schematics. Do you become confused and bewildered when opening a technical order to study a hydraulic system? This is common among those who are just starting their careers as 3-level mechanics. There is no need for this confusion if you follow a logical sequence when studying the schematic. In this chapter we are going to show you how to study a schematic in a logical step-by-step sequence. It is the same sequence that you should follow when studying your own hydraulic system. Of course, we will explain the path of fluid flow and the purpose of each unit as we go along. Understanding of the power system's operation is a must in order to study schematics.

2. We have drawn a complex hydraulic system (see foldout 1 in the back of this volume) that uses many of the units covered in Volume 2. This drawing is not of any particular aircraft but it is representative of any large system. We have designed into this one system a system using a pressure regulator. We also put in a separate system using variable-displacement pumps. In studying this or any other hydraulic schematic, we should follow a logical sequence. First, we have to understand how the system pressure is obtained and maintained. After this is done, we can trace the path of fluid flow through the pressure manifold to any subsystem. Then we concentrate on this one subsystem and, for the time, ignore the other subsystems. We have been using letters to identify units in illustrations in our volumes. TOs generally identify them by placing the names in the illustration. Therefore, we have followed this practice with the foldout illustration. We will also do so in the excerpts from the foldout which will be found throughout the text. Most hydraulic schematics arrange the units (as nearly as possible) in the same relative position as they are on the aircraft. In our schematic we have followed the same general pattern.

3. All valves, actuators, and other units in our schematic have been made as simple as possible. In an effort to preserve simplicity, we have shown mostly slide-type valves. However, these could be rotary or poppet-type and still accomplish the same basic function. These valves can have either O-ring or metal-to-metal seals. We have purposely avoided showing any type of seals.

4. We shall follow a logical sequence in studying the hydraulic schematic shown in the foldout. Of course, we first want to know how the pressure is developed and maintained. Thus, our first subject is the hydraulic power section.

8. Hydraulic Power Section

8-1. The hydraulic power section is shown in figure 23. This section consists of the usual reservoir, pumps, and valves that any other hydraulic power system uses.

8-2. **Reservoir.** Beginning with the reservoir, we see two lines connected to its top. The right-hand line is for reservoir pressurization. The left-hand line provides an air vent for the downside of the main gear actuators. System return fluid is directed up through a venturi-tee for reservoir pressurization. A 15-25 psi check valve is located in the return line to the reservoir. It insures sufficient fluid flow through the venturi-tee. The air for reservoir pressurization is drawn in through an air dehydrator by the venturi-tee. Mounted on the left side of the reservoir is a glass tube-type sight gage. The top and bottom of the glass tube must be vented to the reservoir so that the fluid can rise freely.

8-3. **Pumps.** Connected to the bottom left of the reservior is a line leading to the auxiliary electric pump. It serves as an emergency pump. This pump is electrically driven and may be controlled by one of several switches. The pump's first 1800 psi of pressure is directed to the brake system. In order to have this first 1800 psi directed to the brake system, a priorty valve is used. This particular priority valve is called a selective relief valve. The selective relief valve is basically a balanced relief valve set to open at 1800 psi. When the auxiliary pump is running, its output is directed into the brake accumulator and to the selective relief valve. When the pressure builds up to 1800 psi, the selective relief valve opens. Now the auxiliary pump can also charge the main hydraulic system. The brake accumulator now serves both the brake system and the main system. Any time the main system pressure drops below 1800 psi, the selective relief valve closes. It therby reserves the last 1800 psi available pressure, if the system fails, for the brake system. The maximum output of the auxiliary pump is limited by the auxiliary relief valve. In the schematic, it is located between the electric pump and the system check valve.

8-4. Since you now have an understanding of the auxiliary pump, we will discuss the engine-driven pumps. Our schematic shows two pumps installed on the No. 2 and No. 3 engines. In figure 23, notice that the main supply line to the pumps is connected to the side of the reservoir. With the supply lines connected in this manner, no stand pipe to save fluid for the

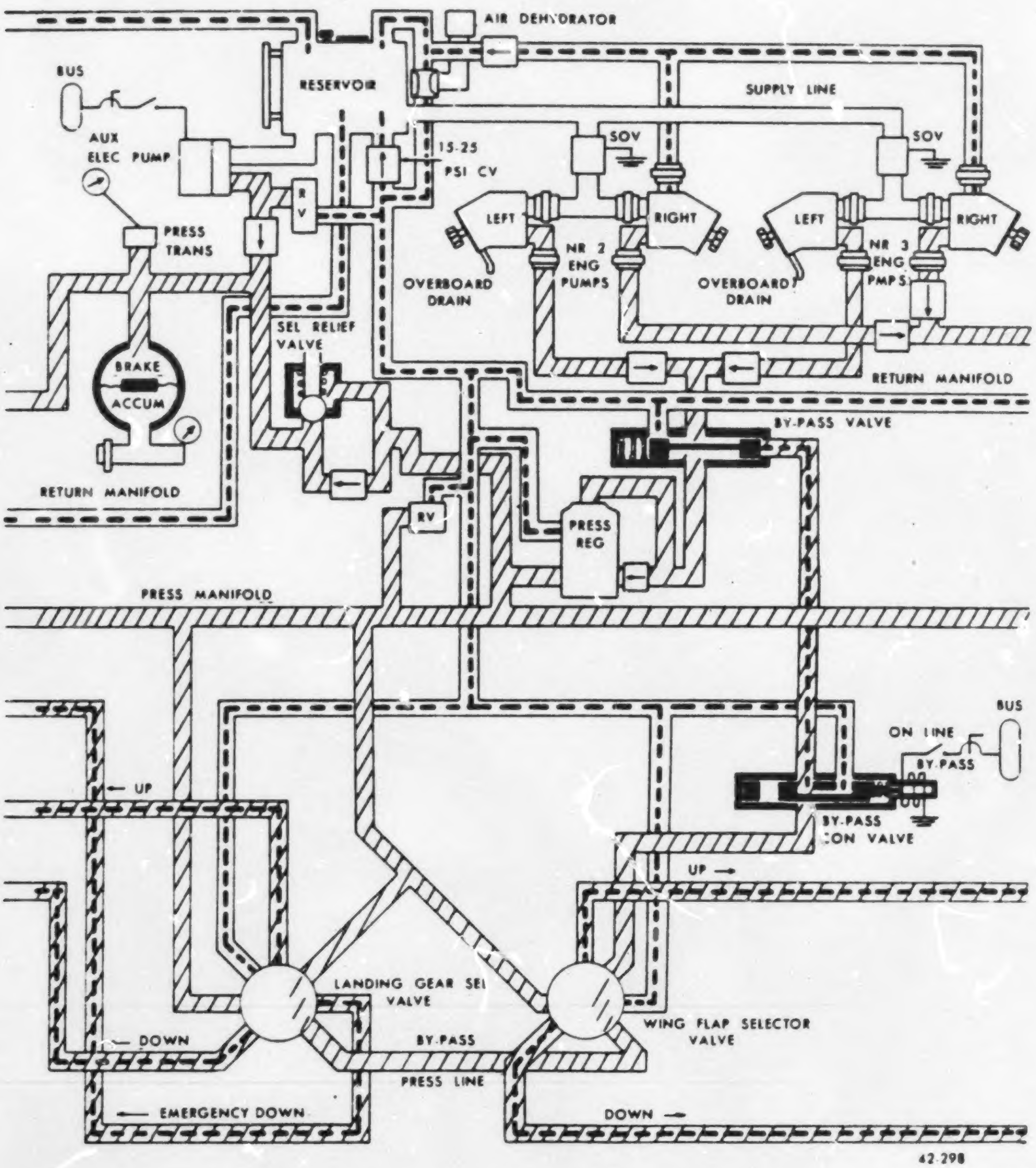
AIR DEHYDRATOR
BUS
RESERVOIR
SUPPLY LINE
AUX
ELEC PUMP
15-25
PSI CV
SOV
SOV
R
V
PRESS
TRANS
LEFT
RIGHT
LEFT
RIGHT
NR 2
ENG
PUMPS
NR 3
ENG
PMPS
OVERBOARD
DRAIN
OVERBOARD
DRAIN
BRAKE
ACCUM
SEL RELIEF
VALVE
RETURN MANIFOLD
BY-PASS VALVE
RETURN MANIFOLD
RV
PRESS
REG
PRESS MANIFOLD
BUS
ON LINE
BY-PASS
UP
BY-PASS
CON VALVE
UP
LANDING GEAR SEL
VALVE
WING FLAP SELECTOR
VALVE
DOWN
BY-PASS
PRESS LINE
EMERGENCY DOWN
DOWN
42-298

Figure 23. Hydraulic power section schematic.

auxiliary pump is necessary. Reservoir fluid level can only be dropped to suction port level by a leak in the main system. Located in the supply lines leading to each engine is an emergency shutoff valve (labled S.O.V.). These valves are electrically operated and are controlled by switches located in the cockpit. These valves can shut off fluid flow to the engine pump in case of emergencies. This schematic has a pressure-regulated power system and also a separate system using variable-volume pumps. Therefore, we need positive displacement pumps and variable displacement pumps. Again in figure 23, you can see that the two left-hand pumps on each engine are the positive-displacement pumps (because they have no fluid return line to the reservoir); the right-hand pumps are the variable-volume pumps. The two variable-volume pumps supply a constant pressure for the flight controls and inflight refueling systems. The two positive-displacement pumps (left-hand pumps) supply fluid pressure for the flaps, landing gear, brakes, nosewheel steering, and cargo loading doors. A regulator and a bypass valve control this pressure. Qick-disconnects are installed in each inlet and outlet of the pump to help make the pump changing easier. Check valves are installed in the outlet of each pump to prevent it from being motorized if it fails.

8-5. **Valves.** The oupput of the left-hand pumps (positive-displacement pumps) is directed down through the bypass valve to the pressure regulator. The pressure regulator is typical of the ones discussed in Volume 2. For discussion purposes, we will say that the regulator has a kick-in pressure of 2700 psi and kick-out pressure of 3000 psi. After the fluid pressure passes through the regulator, it has two paths to follow: one path is to the pressure manifold, and the other one is to the brake system. As the pumps start to rotate, fluid is directed into the brake system through the check valve and into the brake accumulator.

8-6. As the pressure builds up to approximately 1800 psi, the selective relief valve opens. It remains in this position as long as the pressure stays above 1800 psi. Pressure in the system keeps building up until it reaches the kick-out setting of the pressure regulator (3000 psi). Now the flow from the pressure regulator goes back to the reservoir by way of the return lines. The pressure regulator will maintain system pressure between its kick-in and kick-out settings. As previously mentioned, the brake accumulator acts as a main system accumulator above 1800 psi. If system pressure drops below 1800 psi, the selective relief valve closes, isolating the brake system. The positive-displacement pump power system is also protected from excessive pressures by a relief valve. In the schematic, it is located to the left of the pressure regulator. The brake system uses a spherical-type accumulator, with a pressure gage connected to the air chamber. Gages connected in this manner give preload air pressure reading when the hydraulic system is not pressurized. Another pressure gage is located in the flight engineer's or pilot's compartment and is controlled by a pressure transmitter. The transmitter is located in the brake system pressure line. This gage indicates system pressure whenever the reading is above 1800 psi. Otherwise, it indicates the fluid pressure trapped in the brake accumulator.

8-7. During long flights, it is desirable to relieve the load on the engine-driven pumps. This eliminates excessive loading and unloading of the pressure regulator. A bypass system made up of a bypass valve and a bypass control valve is used for this purpose. During normal operation of the hydraulic system, fluid flows through the bypass valve to the pressure regulator. When the bypass control valve is energized to the BYPASS position, the plunger of the control valve moves to the right. This allows fluid pressure from the two selector valves to be directed through the control valve to the bypass valve. The bypass valve plunger is moved to the left, connecting the pump pressure lines to the return manifold. System pressure retained by the check valve will gradually decrease to approximately 250 psi. This is caused by the normal internal leakage of the many hydraulic units. At approximately 250 psi the bypass valve balances itself. The engine-driven pump flow to the return line is restricted enough to maintain approximately 250 psi in the main system. A safety element is installed in the system to help crewmembers who occasionally forget. Should the system be left in bypass during landing, serious consequences could result. The fluid pressure that moves the bypass valve plunger to the left must first pass through the landing gear selector valve. It also flows through the wing flap selector valve before going to the bypass valve. Both of these valves must be in the neutral position for the fluid to pass through them. When either selector valve is actuated, the pressure line from the selector valve to the bypass valve is connected to return. This takes the power system out of bypass and causes it to build up pressure immediately.

8-8. The wing flap selector valve is a six-port type. The ports are *pressure* and *return* ports, *flap up* and *down* ports, and *bypass pressure in* and *out* ports. The landing gear selector valve is a seven-port type. It has *pressure* and *return* ports, *normal up* and *normal down* ports, an *emergency down* port, and *bypass pressure in* and *out* ports. The lines to the selector valves for the landing gear and wing flap are small. They direct fluid to remote or slave control valves. These remote or slave control valves in turn direct fluid from the pressure manifold to the landing gear and wing flap actuators. We discussed remote and slave control valves in another volume of this course. This type of system keeps large high-pressure lines to a minimum and out of the cockpit. This results in weight savings by the use of smaller lines and reduces fire hazard. The selector valves are generally fastened to control levers within easy reach of the operator.

9. Landing Gear Hydraulic System

9-1. The landing gear selected for this discussion is a representative one, to cover theory of operation. The main gear is retracted hydraulically and free-falls in extension. The nose gear retracts and extends hydraulically. The nose gear will not free-fall because it extends forward into the slipstream.

9-2. As previously mentioned, remote control valves direct fluid pressure from the pressure manifold to actuators. Referring to figure 24, we see that there are three of these valves: the *nose gear extension valve*, the *landing gear operating valve*, and the *emergency extension valve*.

9-3. **Gear Retraction.** After takeoff, the copilot moves the control handle to the UP position. Fluid pressure is directed from the selector valve, through the up line, to the landing gear operating valve. The pressure forces the plunger to the left, opening a passage through the valve for fluid to flow. The pressure is directed to the *up* side of the main gear actuators for retraction. Fluid is also directed to the *unlatch* side of the nose gear downlatch actuator. It is also directed to the *up* side of the nose gear retracting actuator. The downlatch actuator releases an over-center lock mechanism so that the nose gear can then be retracted. The initial movement of the main gear actuator breaks an overcenter mechanism which allows the gear to retract. An overcenter lock mechanism is also used to hold the gears in the retracted position. The gears strike this overcenter mechanism as it reaches the full up position. The mechanism is spring-loaded to lock around the actuators. These uplocks are released by hydraulic actuators.

9-4. By now you may be wondering what an overcenter lock mechanism is. One example is the metal bracket that holds the cover door open on a phonograph. Once the cover is opened and the metal bracket pushed overcenter, normally the door cannot close by itself. The door will stay open until the bracket is pulled from the overcenter position. Another example is a stepladder. When the ladder is opened out, a centering handle is pushed down, thus locking the ladder in the open position. This lock is an overcenter mechanism.

9-5. After the three gears are locked in the UP position, the control lever is moved to the NEUTRAL position. This vents the right-hand

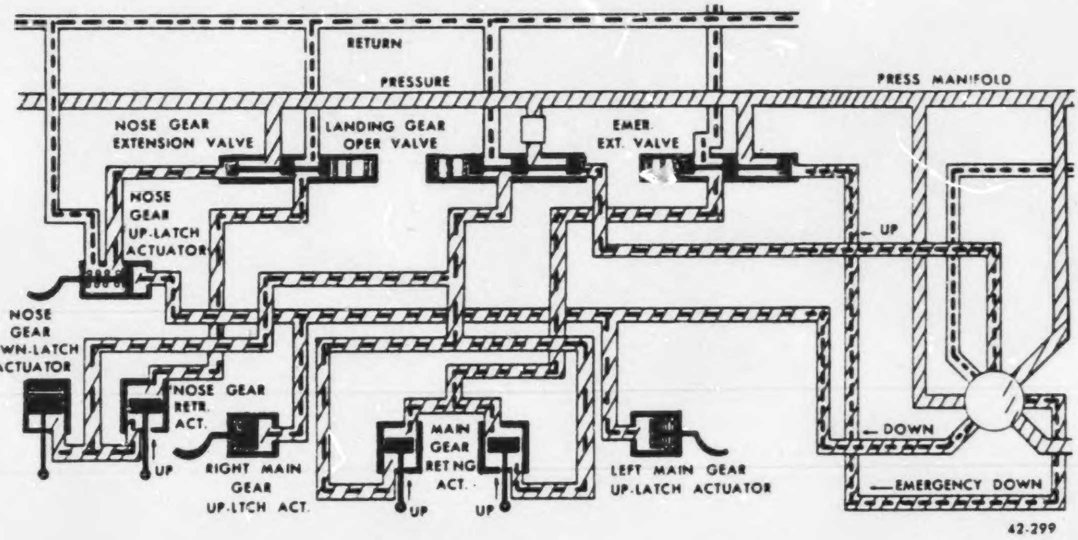
RETURN
PRESSURE
PRESS MANIFOLD
NOSE GEAR EXTENSION VALVE
LANDING GEAR OPER VALVE
EMER. EXT. VALVE
NOSE GEAR UP-LATCH ACTUATOR
UP
NOSE GEAR OWN-LATCH ACTUATOR
NOSE GEAR RETR. ACT.
UP
RIGHT MAIN GEAR UP-LTCH ACT.
MAIN GEAR RETNG ACT.
UP
UP
LEFT MAIN GEAR UP-LATCH ACTUATOR
DOWN
EMERGENCY DOWN
42-299

Figure 24. Landing gear hydraulic system shcematic.

port of the landing gear operating valve to the return manifold. The plunger in the landing gear operating valve then returns to the *normal* position. This position vents the up lines of all three landing gear actuators to the return manifold. The nose gear downlatch is also vented to the return. The internal spring moves its actuator piston back to its original position. Some systems you will encounter do not require moving the selector handle to neutral.

9-6. **Gear Extension.** During normal extension procedures, the control lever is moved to the DOWN position. The selector valve now directs fluid pressure to the unlatch side of the main gear uplatch actuator. It also directs fluid to the nose gear uplatch actuator. After the main gear uplatches are released, the two main gears free-fall into the extended position. A bungee or springs may be installed on the main gear to insure that they are completely down and locked. As the gear falls, hydraulic fluid is forced out of the *up* side of the actuators to the return. The down sides of the actuators are vented to the top of the reservoir through the emergency extension valve. Venting the down sides of the actuators to the top of the reservoir causes them to merely draw in and expel air during normal operation. However, during EMERGENCY DOWN operation, this line is connected to the pressure manifold. (This is explained in a later section.)

9-7. As previously mentioned, the nose gear does not free-fall during extension. The nosegear uplatch actuator has a special feature built into it; namely, a sequence valve. This prevents pressure being applied to the nose gear until after the uplatch is completely released. When the uplatch is released, fluid is directed through the uplatch actuator to the nose gear extension valve. Pressure forces the plunger or slide of the extension valve to the right. Fluid can now flow from the pressure manifold to the *down* side of the nose gear actuator. When the gear reaches the full down position, it hits an overcenter lock mechanism, which locks it. You may be wondering why we want the uplatch released before applying pressure to extend the gear. Yet we don't release the downlatch before applying the pressure for retracting the gear. The weight of the gear alone imposes a considerable strain on the uplatch mechanism. Therefore, if hydraulic pressure is applied to extend the gear before it is unlatched, structural damage may result. When the gear is down and locked, the control handle is moved to the NEUTRAL position. Then the piston of the nose gear uplatch actuator will return to its normal position. The nose gear extension valve plunger also returns to its normal position.

9-8. **Emergency Gear Extension.** Should either or both main gears bind and not extend completely, hydraulic fluid can force them down. If the gear binds, locate the trouble, if possible, before using the emergency procedure. If hydraulic pressure is to be used, the control lever is moved to the EMERGENCY DOWN position. In this position the selector valve opens two pressure outlet lines. One directs fluid through the emergency down line to the emergency extension valve. The other directs fluid to the main and nose gear uplatches; this is the normal down line. The slide of the emergency extension valve is moved to the left by the fluid pressure. This closes off the air vent line to the reservoir. At the same time, it opens a passage from the pressure manifold to the down side of the main gear retraction actuators. The gear is extended by hydraulic pressure. After the gear is down and locked, the control handle is moved to either the DOWN or NEUTRAL position. Most aircraft technical publications require that the control handle be left in the DOWN position. This is a safety precaution when the aircraft is on the ground.

9-9. If system pressure is lost during flight, some sort of landing gear emergency extension system must be provided. In the system we selected, this is done by mechanically releasing the three uplatches. In such a case, the pilot or copilot pulls a control lever marked "Emergency Gear Extension." Through cables and linkages, the overcenter locks are released. This frees all three gears from their uplatches. The two main gears free-fall into extension. Now, how about the nose gear? We have said that it extends forward into the slipstream. This is true, but we still can get the gear down without the use of hydraulic pressure by aircraft maneuver technique. The correct procedures naturally are outlined in the appropriate technical order.

9-10 We have not forgotten about the wheel well doors. We have drawn this aircraft schematic so that the doors open and close mechanically. This is the case with several of our large aircraft. When hydraulic pressure is used for opening and closing of the doors, proper sequencing is needed. Actuators and sequence valves insure that the doors and gear move in their proper time.

9-11. When we have landing gears, we must have brakes. Thus, our next discussion centers about the brake system schematic.

10. Brake System

10-1. The brakes are operated either by hydraulic pressure or by air pressure. (See fig. 25.)

10-2. **Normal Hydraulic System.** The normal system consists of the brake accumulators, two power brake control valves (PBCVs), shuttle valves, and the brake units. The accumulator is charged either by the auxiliary pump or by the normal system through the selective relief valve. Braking pressure is controlled by two power brake control valves. These valves (one for the right wheels and one for the left wheels) are controlled by the ppilot's and copilot's rudder pedals. Figure 25 shows only one set of pedals; however, two are used whenever the aircraft requires more than one pilot. When the brake pedals are depressed, the power brake control valves direct fluid to the brake shuttle valves. From the shuttle valves the fluid is directed to the brake assemblies. The shuttle valves normally block off the air pressure lines. The hydraulic pressure and a spring cause the shuttle valve to close the air lines. When the brake pedals are released, the PBCVs are closed to pressure and opened to the return manifold. The brake return springs then release the brakes. They force the fluid back through the PBCVs to the return line and on to the reservoir. Most brake systems have some type of a safety device to prevent excessive loss of fluid. Hydraulic fuses will do this job very well. As you recall, hydraulic fuses close and block the line after a measured volume of fluid has passed through them.

10-3. **Emergency Air System.** In the case of hydraulic failure, the air brake system provides the necessary pressure to apply the brakes. The air brake system consists of an air bottle, pressure gage, and two air brake valves. Two hand-operated control levers actuate the brake valves during emergency operation. These levers are generally painted red and safetied (with small safety wire) in the OFF position. When the control levers are moved to ON, the air brake valves direct air to the shuttle valves. The applied air pressure moves the shuttle in the shuttle valves. This closes the brake hydraulic lines and opens the air line to the brake units. Air pressure applied to the brake units is directly proportional to the movement of the control levers. When the control levers are released, the brake valves shutoff the pressure from the air bottle. Also, the pressurizing air charge is vented overboard. The pressure in the air bottle is generally sufficient for two or three applications of the brakes. Whenever air has been used, the brakes must be bled before the normal hydraulic brakes can be used. If not bled, the air trapped in the brakes will give erratic operation.

10-4. You may be asking, "Why use air instead of hydraulic fluid for emergency operation?" This is a question that has to be answered when the aircraft is designed. Many factors must be considered when determining the type of system to be used; for instance, the size of the aircraft, the ease of locating the emergency system, and the weight factor of air compared with hydraulic fluid must all be given consideration.

11. Nosewheel Steering and Cargo Door Hydraulic Systems.

11-1. One might not consider the nosewheel steering and the cargo door hydraulic system as

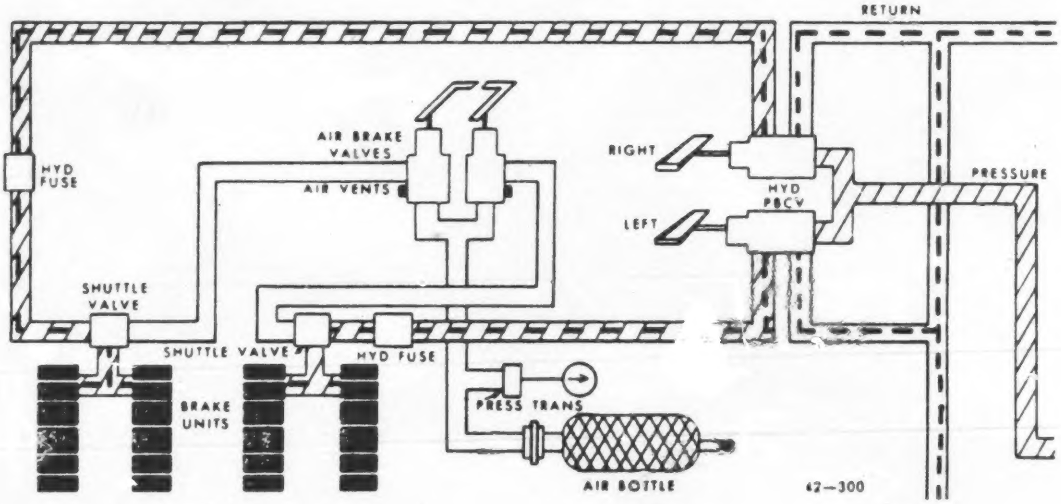

Figure 25. Brake system (hydraulic and air).

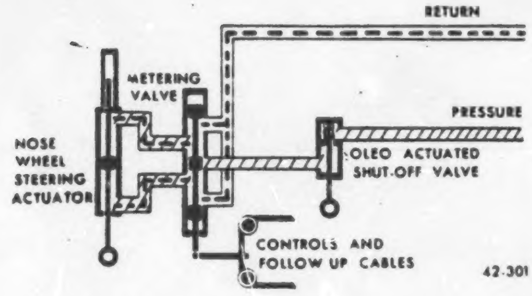
RETURN
METERING VALVE
PRESSURE
NOSE WHEEL STEERING ACTUATOR
OLEO ACTUATED SHUT-OFF VALVE
CONTROLS AND FOLLOW UP CABLES
42-301

Figure 26. Nosewheel steering hydraulic system schematic.

essential as landing gear and brake systems. Yet, they are highly important. Sometimes they are rather complex.

11-2. **Nosewheel Steering.** The nosewheel steering system, shown in fig. 26, is relatively simple in design and operation. The system consists of an oleo-actuated shutoff valve, metering valve, a balanced-type actuator, and followup mechanism.

11-3. Fluid from the pressure manifold is directed through the oleo-actuated shutoff valve to the slide-type metering valve. The oleo-actuated shutoff valve is closed whenever the nose strut is almost fully extended. This prevents accidental use of steering when the aircraft is airborne. Centering cams center the nosewheel when the strut extends toward its maximum extension. If steering could be used after the cams became engaged, severe damage could result to the centering mechanism.

11-4. The slide-type metering valve is cable controlled from the cockpit by a steering wheel. Turning of the steering wheel causes the slide valve to move, thereby sending fluid to the actuator. The actuator is a balanced type, allowing the turning force to be equal in either direction. As the actuator turns the nosewheel, a followup system returns the slide to its neutral position. The type system used is decided by the design engineers.

11-5. If hydraulic pressure is lost, the nosewheel will caster freely. Centering springs hold the slide valve in its neutral position. In this position, fluid can free-flow from one side of the actuator to the other. No shimmy damper is required on this system, assuming corotating wheels are used. In an earlier volume, we discussed this type of system in detail.

11-6. **Cargo Loading Door.** When the door is open, the front end of the cargo loading door extends down onto the ground. It forms a ramp for small vehicles to drive into the aircraft. The hydraulic system (see fig. 27) consists of a rotary-type selector valve, two mechanically operated sequence valves, a one-way check valve, two latch actuators, two door actuators, and an emergency hand pump and reservoir.

11-7. Let's assume that the door is closed the selector valve has been placed in the OPEN position. Hydraulic fluid from the pressure manifold is directed to the two door-latch ac-

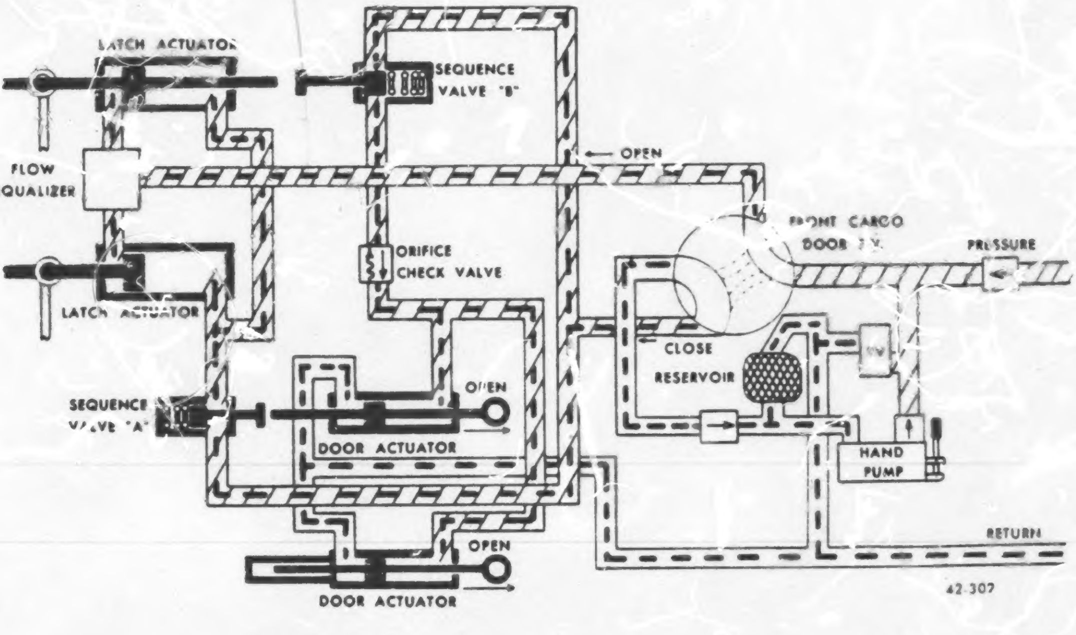
LATCH ACTUATOR
SEQUENCE VALVE "B"
FLOW EQUALIZER
OPEN
FRONT CARGO DOOR S.V.
PRESSURE
ORIFICE CHECK VALVE
LATCH ACTUATOR
CLOSE
RESERVOIR
SEQUENCE VALVE "A"
OPEN
DOOR ACTUATOR
HAND PUMP
RETURN
OPEN
DOOR ACTUATOR
42-302

Figure 27. Cargo-loading door hydraulic system schematic.

tuators through a flow equalizer valve. The flow equalizer insures that both latch actuators actuate at the same time.

11-8. Pressure forces the pistons of both latch actuators to the right. Return fluid is directed through sequence valve A. At this point of operation, sequence valve A is being held open by one of the door actuators. As each latch actuator moves to the right, two things happen: the latches are first released, and then sequence valve B (located in the door actuator return line) is opened.The door then falls open by its own weight. While sequence valve B was closed, the doors could not open. This was because valve B trapped the fluid in the *close* side of the two door actuators. During door opening, fluid in the *close* side of the door actuators is routed through the orifice check valve, and sequence valve, to return. Sequence valve B insures that the latches are fully released before the door is allowed to drop again. The orifice check valve slows the opening rate of the door. The opening of the doors allows spring force to close sequence valve A. This positions sequence valve A for the proper door-closing sequence.

11-9. When the cargo door selector valve is moved to the CLOSED position, hydraulic fluid is directed through the open sequence valve B. The flow is unrestricted to the close side of the door actuators. Fluid flow to the latch actuators is blocked by closed sequence valve A. As the doors reach the full closed position, sequence valve A is opened. This allows hydraulic fluid to be directed to the latch side of the latch actuators. As the latch actuators start moving toward the latched position, sequence valve B closes. This positions sequence valve B for proper door-opening sequence. The selector valve has only two positions; therefore, it is normally *left* in the door's selected position. An auxiliary hand pump provides hydraulic pressure for door operation if normal pressure is unavailable. Return flow from the selector valve to the return manifold must first pass through the auxiliary reservoir. Thus, normal operation of the doors insures that the reservoir is always full of fluid. The capacity of a reservoir used in a system such as this ranges from 1 quart to 1/2 gallon. This is sufficient in size because the fluid in the reservoir is only a reserve supply to compensate for normal leakage. A hand pump relief valve is connected between the hand pump outlet line and the return line. The setting of this valve is generally between 200 and 300 psi above the normal system pressure.

11-10. As we have previously stated, this system is not for any particular aircraft, but it is typical of many sequence systems presently used.

12. Flight Control Actuating Systems

12-1. Some flight control surfaces such as wing flaps are moved entirely by hydraulic power. Others—like ailerons, rudders, and elevators—are often moved by the pilot's energy plus hydraulic boost force. We will cover the wing flap and aileron boost systems as representative examples. We will also touch on tab actuation of control surfaces.

12-2. **Wing Flap System.** The wing flaps are raised and lowered through the use of a hydraulically driven motor. The direction of travel is controlled by a selector valve in the cockpit area. It, in turn, actuates a remote control valve similar to the ones used in the landing gear hydraulic system.

12-3. Figure 28 is an excerpt from the foldout and shows the complete wing flap hydraulic system. Let's assume that the flaps are up and that the wing flap selector valve is moved to the DOWN position. Hydraulic pressure is directed to the *down* side of the wing flap control valve. The slide in the control valve moves up. This lets system pressure pass through the down line to the wing flap limit valve. From there it goes to the hydraulic motor. As the fluid leaves the wing flap control valve, it also enters the bottom side of the shuttle valve. It pushes the shuttle up and passes on to the wing flap lock valve. The pressure then pushes this valve down and passes on to the brake assembly in the hydraulic motor. The pressure releases the brake and thereby permits the motor to lower the flaps. As the motor turns, it lowers the slide in the wing flap limit valve through mechanical linkage. As the flaps approach their *full down* position, the slide blocks the down line and stops the motor. Adjustment of this linkage sets the *up* and *down* limits of the flap travel.

12-4. Let's see what happens when we decide to raise the flaps. Moving the selector valve to the UP position sends fluid to the top of the wing flap control valve. This pushes the slide down and lets fluid pass through into the up line. From there it pushes the shuttle valve down and passes on to the wing flap lock valve. Again, it goes on to the motor brake and releases it. Up line fluid also flows through the wing flap limit valve and on to rotate the hydraulic motor. Before, when we lowered the flaps and reached *full down*, the limit valve's slide had also moved down. It blocked the down pressure line completely. If it is blocked off, how then can it become the return line for the motor during "flap up" operation? Notice the two ball check valves in the limit valve.

They provide an alternate path for fluid return until the slide moves far enough to unblock the ports. When the flaps reach their up limit, the slide will block the *up* line.

12-5. The flaps can be stopped at any in-between position by placing the selector valve in NEUTRAL. This positions the selector valve so that *both* lines going to the control valve are vented to return. The slide in the control valve will be held in the *netural* position by the centering springs. As a result, all up and down lines to the motor will be unpressurized. No pressure will turn the motor and no pressure will unlock the brake; the flaps will remain stationary.

12-6. Most hydraulic motors have speed-governing device. Flow control or constant flow valves serve this purpose. Our flap hydraulic system uses one of these valves for that purpose. Figure 28 shows the constant flow valve connected into the pressure line going to the wing flap control valve. Having the valve located in the pressure line means that only one valve is needed. It can control the speed of the flaps in either the raising or lowering operation.

12-7. **Aileron Boost System.** The aileron boost system receives its pressure from another source than the systems discussed up to now. It gets its pressure from two engine-driven *variable-displacement* pumps. You may be wondering why we don't use the normal regulator-controlled system for the aileron boost. Early in this chapter, we said that we needed to relieve the system of high pressure during long flights. The aileron boost does not require large quantities of fluid at any one time. However, it uses small, varying amounts of fluid under pressure *continuously*. The variable-displacement pump, also called variable-volume pump, meets this need.

12-8. The system, shown in figure 29, is a relatively simple one. It consists of a boost control unit, a priority valve, a relief valve, and an accumulator. The boost control unit consists of a metering valve and an actuating cylinder. The actuating cylinder's piston rod (left end) is fastened to the structure of the aircraft and, therefore, does not move. The ailerons are mechanically fastened to the right-hand side of the cylinder housing, which does move. The metering valve slide unit (bottom in actuator) is attached by linkage to the control stick or wheel. Whenever the pilot makes an aileron change motion on his control, this slide moves with it.

12-9. Let's assume that the slide valve is moved to the right. Fluid is then directed into the right end of the actuating cylinder. Since the piston cannot move, the entire housing assembly has to move to the right. It thereby moves the control surface. As the cylinder housing catches up with the metering valve, the amount of fluid going into the cylinder tapers off. When it has caught up, the passage to the right end of the cylinder is blocked. This stops further movement of the cylinder assembly. The slide traps the fluid in both ends of the cylinder, thereby holding the control surfaces stationary. In the event hydraulic pressure is lost, the ailerons can be controlled mechanically. Normally, system pressure pushes up on the center plunger shown in the figure. When it is pushed up, it blocks the passage which connects the two end chambers of the cylinder. When system pressure is lost,

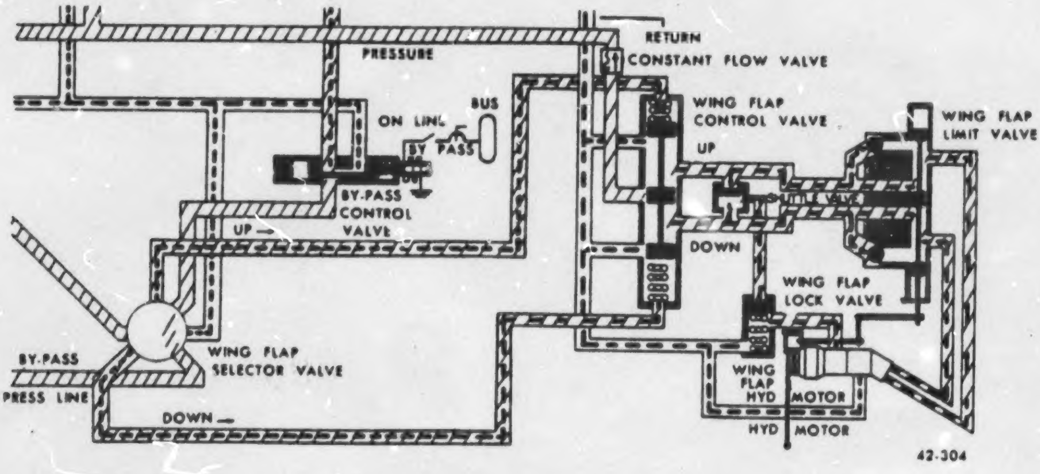

Figure 28. Wing flap hydraulic system schematic.

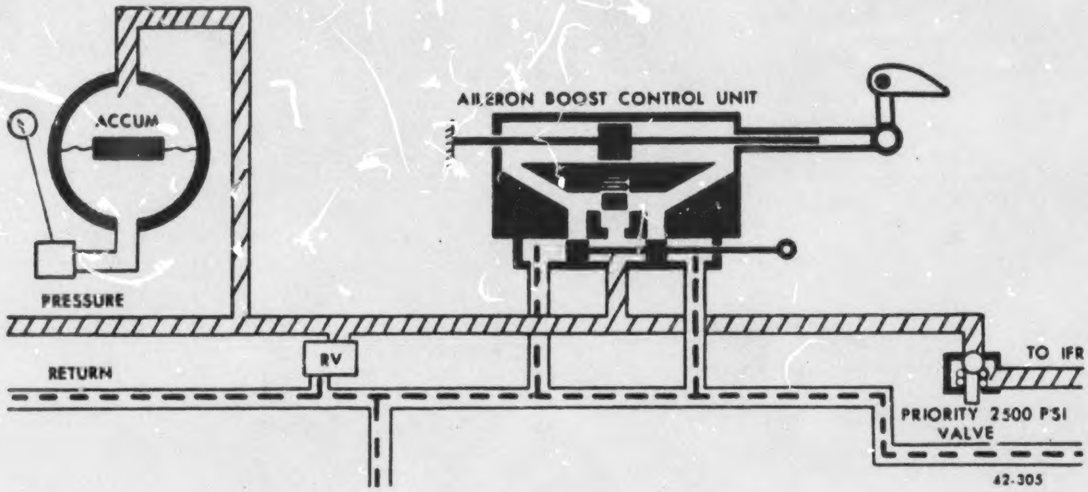

Figure 29. Aileron boost hydraulic system schematic.

the spring pushes the plunger down, opening the passageway. Now there can be free flow of fluid between the two sides of the actuating piston. The linkage now moves the entire control unit and aileron without hydraulic boost.

12-10. The priority valve is installed to insure that the aileron system has priority over the inflight refueling system. The relief valve protects the system from excessive pressure. The accumulator is installed to dampen pressure surges caused by rapid starting and stopping of units.

12-11. Many of our more recent aircraft don't rely entirely on ailerons for lateral control of the aircraft; instead, they use spoilers either alone or together with the ailerons. Spoilers serve the same basic purpose as ailerons, but they control the aircraft in a different manner. As an example, to lower the right wing of an aircraft using ailerons, the right aileron rises and the left aileron lowers. To lower the right wing of an aircraft using spoilers, only the right spoiler rises. Most spoiler systems can also be used as speed brakes. However, when used as speed brakes, both spoilers are raised at the same time.

12-12. **Tab Actuation.** Some aircraft may have hydraulic boost systems for the rudder and elevators. Other aircraft use flying or servo tabs to move the control surfaces. These tabs are a small control surface installed in the trailing edge of the main control surfaces. The pilot's control stick is usually mechanically fastened to these tabs. The mechanical linkage is such that the tabs are moved in the opposite direction of the control surface. On aircraft with autopilots, there may be hydraulic involvement in tab actuation. We won't go into that, because it is the responsibility of another AFS.

12-13. This completes our discussion of a typical hydraulic system and the reading of schematic diagrams. However, hydraulics are used for many purposes other than for flying and controlling the aircraft. For example, hydraulics are used to operate bomb doors, guns, and inflight refueling systems. Some of these systems are maintained by personnel other than the pneudraulic repairman.

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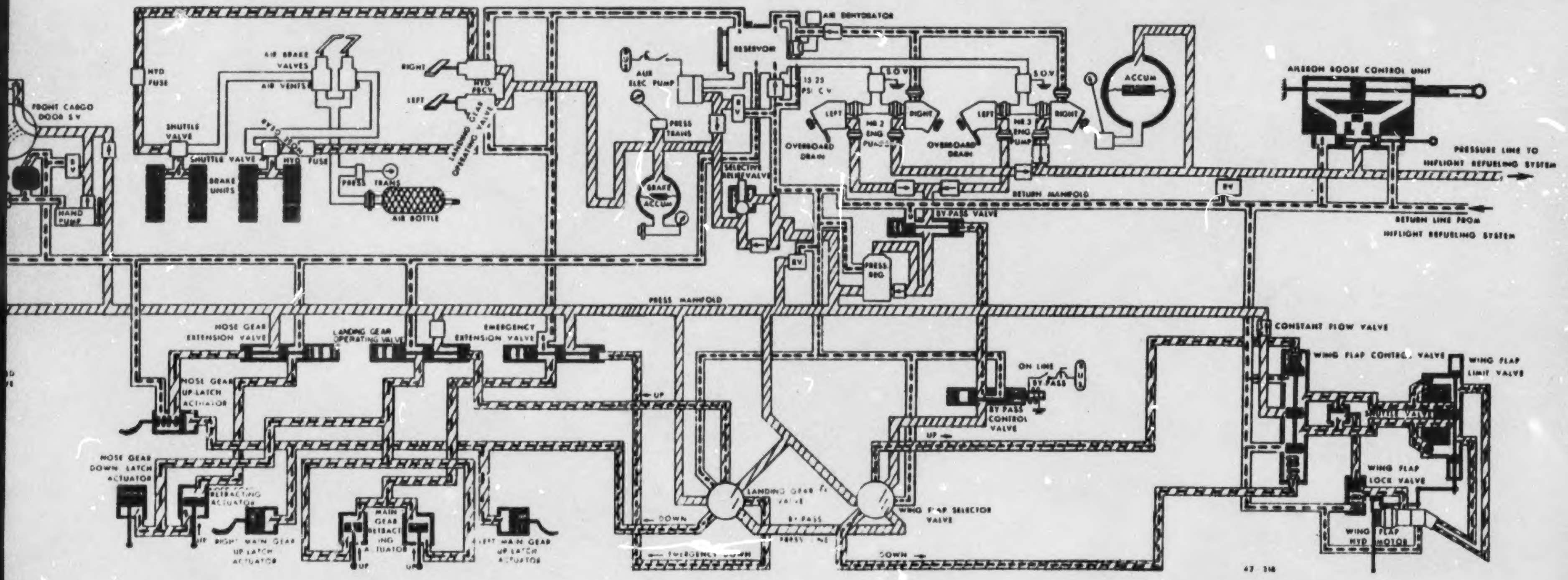
MODIFICATIONS

Chapter 3 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.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HAND PUMP
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AILERON BOOST CONTROL UNIT
PRESSURE LINE TO INFLIGHT REFUELING SYSTEM
RETURN MANIFOLD
RV
RETURN LINE FROM INFLIGHT REFUELING SYSTEM
BY PASS VALVE
RV
PRESS REG
PRESS MANIFOLD
NOSE GEAR EXTENSION VALVE
LANDING GEAR OPERATING VALVE
EMERGENCY EXTENSION VALVE
NOSE GEAR UP LATCH ACTUATOR
NOSE GEAR DOWN LATCH ACTUATOR
NOSE GEAR RETRACTING ACTUATOR
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RIGHT MAIN GEAR UP LATCH ACTUATOR
MAIN GEAR RETRACTING ACTUATOR
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UP
LEFT MAIN GEAR UP LATCH ACTUATOR
UP
DOWN
EMERGENCY DOWN
LANDING GEAR VALVE
BY PASS
PRESS LINE
WING FLAP SELECTOR VALVE
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UP
ON LINE
BY PASS
BY PASS CONTROL VALVE
CONSTANT FLOW VALVE
WING FLAP CONTROL VALVE
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SHUTTLE VALVE
WING FLAP LOCK VALVE
WING FLAP HYD MOTOR
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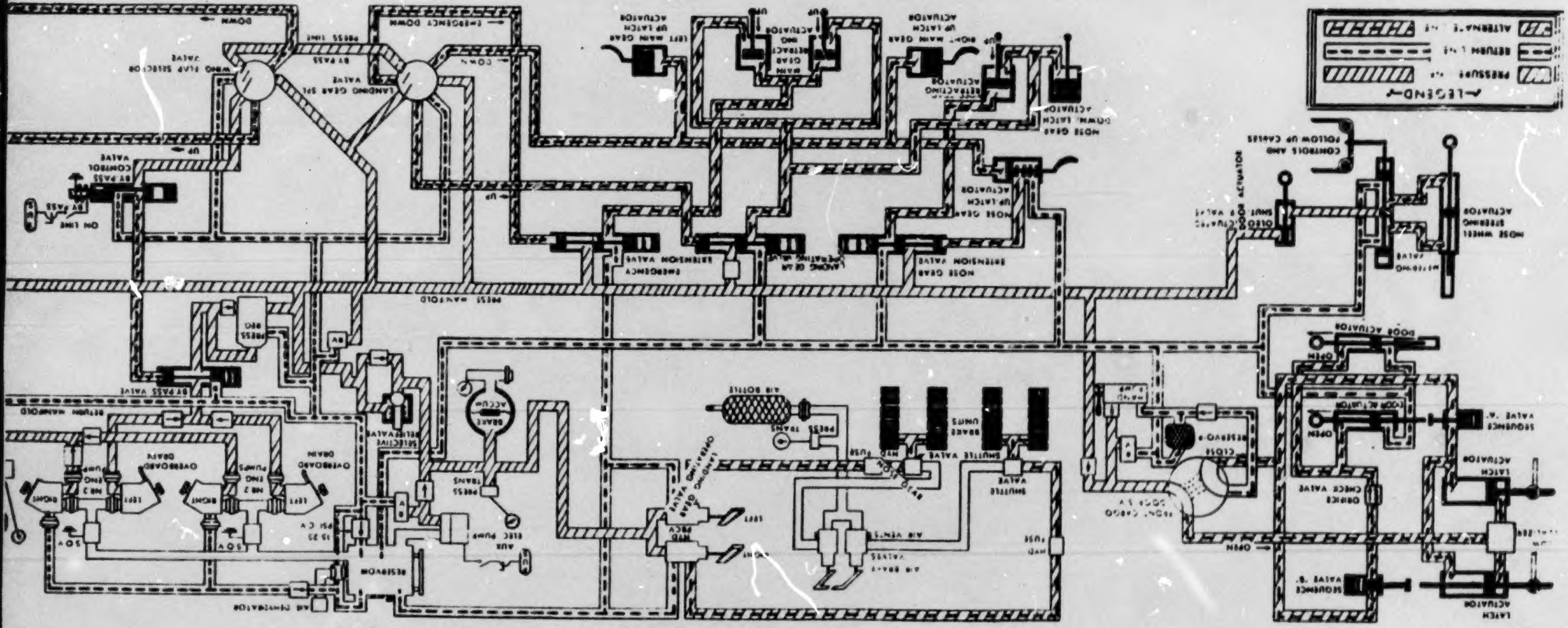
Foldout 1. Aircraft hydraulic system schematic.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BY PASS
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LANDING GEAR SEL VALVE
BY PASS CONTROL VALVE
ON LINE
BY PASS
LEFT MAIN GEAR UP LATCH ACTUATOR
MAIN GEAR RETRACT ACTUATOR
RIGHT MAIN GEAR UP LATCH ACTUATOR
NOSE GEAR RETRACTING ACTUATOR
NOSE GEAR DOWN LATCH ACTUATOR
NOSE GEAR UP LATCH ACTUATOR
EMERGENCY EXTENSION VALVE
LANDING GEAR OPERATING VALVE
NOSE GEAR EXTENSION VALVE
PRESS MANIFOLD
PRESS REG
BY PASS VALVE
RETURN MANIFOLD
SELECTIVE VALVE
BRAKE ACCUM
PRESS TRANS
AUX ELEC PUMP
RESERVOIR
ENG PUMPS
OVERBOARD DRAIN
AIR BOTTLE
BRAKE UNITS
SHUTTLE VALVE
AIR BRAKE VALVES
CONTROLS AND FOLLOW UP CABLES
DOOR ACTUATOR
SHUT OFF VALVE
NOSE WHEEL STEERING ACTUATOR
SEQUENCE VALVE
LATCH ACTUATOR
CHECK VALVE
ORIFICE
OPEN
CLOSE

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WORKBOOK

GROUND EQUIPMENT, SCHEMATICS, AND SUPERVISION AND TRAINING

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ECI Form No. 17

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STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate the numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number

Guide Numbers 400 through 413

400 Introduction to Shop and Aerospace Ground Equipment; HCT–6 Hydraulic Component Tester: Internal High-Pressure Pump Circuit; Component Test Circuit; Cylinder Test Circuit; Pump Test Circuit; pages 1–6

401 HCT–6 Hydraulic Component Tester: Foot Pump Test Circuit; High-Pressure Air Pump Circuit; Manometer Circuit; Return Circuit; Temperature Control Circuit; Air Pressure Circuit; Vacuum Circuit; Operating Instructions; pages 6–9

402 Portable Hydraulic Test Stands; pages 9–14

403 Hose and Fitting Assembly Machine; pages 14 16

404 Jacks; pages 16–20

405 Maintenance Stands; pages 20–22

406 Portable Air Compressors; pages 22–27

407 Ultrasonic Filter Cleaning; pages 27–30

Guide Number

408 Introduction to Use of Hydraulic Schematics; Hydraulic Power Section; pages 31–34

409 Landing Gear Hydraulic System: Brake System; pages 34 36

410 Nosewheel Steering and Cargo Door Hydraulic Systems; Flight Control Actuating Systems; pages 36–40

411 Introduction to Supervision and Training; Supervision; pages 41–42

412 On-the-Job Upgrade Training: What Is OJT?; When Is OJT Needed?; Who Needs OJT?; How is OJT Conducted?; Duties and Responsibilities for OJT; pages 42 45

413 On-the-Job Upgrade Training: Commanders; The Squadron OJT Supervisor; The Section Supervisor; The OJT Trainee; The CE Testing Office; Administration of the OJT Program; Status of Training; Personnel Actions; Monitoring OJT Training; AF Form 623; pages 45–55

CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

CHAPTER 1

Objectives: To become familiar with the various items of aerospace ground equipment and to be able to use them effectively and to keep them in proper working order.

1. What are the main functions of any testing equipment that may be found in a maintenance shop? (Intro.-1-3)

2. What is the function of the internal high-pressure pump circuit of the HCT-6 test stand? (1-3)

3. Which circuits does the reservoir of the HCT-6 test stand supply fluid to? What is the rated capacity of the reservoir in gallons? (1-4)

4. What is the source of the air for pressurizing the reservoir of the HCT-6? At what psi can the reservoir be pressurized? (1-5)

5. If the suction filter in the HCT-6 test stand becomes clogged, what protects the pump? (1-6)

6. What is the purpose of the volume control on the HCT-6 test stand? (1-7)

7. Why should the HCT-6 test stand relief valve never be adjusted below 500 psi? (1-7)

8. What protects the hydraulic pump from excessive pressures when it is supplying power for testing on the HCT-6? (1-7)

9. What purpose does the accumulator on the HCT-6 test stand serve in the component circuit? (1-8)

10. For what purpose is the pump test circuit on the HCT–6 used? (1-10)

11. What protects the foot pump circuit of the HCT–6 test stand from excessive pressure? (1-13)

12. What are the six test circuits of the HCT–6 test stand? (1-7–10, 13, 16; Fig. 2)

13. What is the high-pressure air pump circuit of the HCT–6 test stand used for? (1-16–19)

14. What prevents the mercury from being blown out of the manometer on the HCT–6 test stand? (1-21)

15. When setting up the HCT–6 test stand, what safety precaution should you take in regard to positioning the range selector valve handle to the flow meters? (1-24)

16. What prevents overheating the fluid in the reservoir? (1-26)

17. How can the fluid of the HCT–6 test stand be maintained at a desired temperature? (1-27–29)

18. On the HCT–6 test stand, what unit can be used to check case pressure of a pump or back pressure of a unit being tested? (1-34)

19. Explain the purpose of the cylinder test circuit on the hydraulic HCT–6 test stand. (1-9, 37)

20. In what position is the flowmeter range selector valve when starting the HCT–6 test stand? (1-37)

21. For what purpose will you use a portable hydraulic test stand? (2-1)

22. The portable test stand replaces what unit(s) of the aircraft system? (2-1)

23. How many hydraulic systems does the MK–3 have? What purposes are they used for? How can they be operated? (2-5)

24. What determines the source of fluid to the boost pumps of the MK–3? (2-6)

25. What limits maximum fill system pressure on the MK–3? (2-12)

26. Why is it best to have the bypass valve open when you start a test stand? (2-14)

27. What step must you take before connecting the MK–3 to the aircraft? (2-15)

28. What caution should you take in positioning the reservoir selector with the MK–3 running and flow control valve open? (2-19)

29. What advantage is there to you in using the hose assembly machine instead of the hand method? (3-1)

30. What should you check before you start to set up the hose assembly machine? (3-5)

31. Using a hose assembly machine, you have just completed the part of the operation to determine that the fitting clearance is correct. What are the next three steps? (3-10)

32. What should you do before you attempt to operate the hose assembly machine? (3-11)

33. Before jacking an aircraft, why should you check the maintenance technical manual? (4-1)

34. What determines which jack may be used on aircraft? (4-4)

35. What is the purpose of the air vent on a jack reservoir? (4-6)

36. What prevents accidental lowering of a jack, when it is under a load? (4-9)

37. How would you remove trapped air from a jack ram cylinder? (4-11)

38. Where is the filler plug for an axle jack? (4-13; Fig. 13)

39. Why are jack pads used with tripod jacks? (4-14)

40. When you are ready to jack an aircraft, what should you check before placing the jacks under the aircraft? (4-15)

41. Why is it advisable to remove the jacks from beneath the aircraft quickly after lowering? (4-16)

42. Why is the position of the wheels of a jack important while jacking an aircraft? (4-16)

43. Ideally, how many men are needed to jack an aircraft? (4-18)

44. What is the advantage of using a jacking manifold when raising more than one jack? (4-19)

45. When should you inspect a jack for its general condition? (4-21)

46. When the B–1 maintenance stand is extended, what gives it added stability? (5-6)

47. What safety precaution should you take before ascending the stairs of B–1 maintenance stand? (5-7)

48. What controls the speed of lowering a maintenance stand? (5-8)

49. What is the maximum load that should be raised on the B–1 platform? (5-10)

50. How many air systems does the MC–1 air compressor have? (6-3)

51. What prevents the MC–1 engine from being started under a load? (6-5)

52. What unit of the MC–1 air compressor removes the last traces of water from the compressed air? (6-8)

53. What limits are there on the use of the low-pressure chuck of the MC–1 air compressor? (6-15)

54. What should you check first before starting an air compressor? (6-17)

55. In what position is the pilot valve when starting the MC–1 (Joy) air compressor? Explain how you adjust the valve to the starting point? (6-18)

56. If you want to use the MC–1 air compressor in a closed area, what precaution should you take? (6-18)

57. Why are the service line relief valves opened after completing the servicing of a unit? (6-23)

58. You have just finished servicing an aircraft strut, using the high-pressure air system. What possible danger is there if you accidentally open the service valve? (6-27)

59. For what purpose is the ultrasonic cleaner used? (7-3)

60. Name the two classes of transducers. (7-5)

61. Cleaning in the ultrasonic cleaner is accomplished in two ways. Name them. (7-7)

62. When sonic energy is applied to the cleaning solution, what is the collapse of the cavities called? (7-9)

63. What does the actual scrubbing of the filter element in the ultrasonic cleaner? (7-10)

64. Will large air bubbles affect the cleaning operation of the ultrasonic cleaner? Explain. (7-11)

65. What is the precaution needed in handling the cleaning fluids of the SANE 50? (7-12)

66. What prevents the vapors of trichlorethylene from rising above a safe level? (7-17)

67. What should you do with a woven wire mesh filter before you clean it? (7-19)

68. How do you know if the filter element you're cleaning is clean? (7-22)

69. You are performing the bubble test on a filter element and a larger column of bubbles appears at one point. What does this mean? What choice of maintenance do you have? (7-24)

70. What precaution should you take after you have cleaned a filter? (7-25)

71. How much of the total surface of a filter element can be repaired before it is discarded? (7-29)

CHAPTER 2

Objective: To learn to read and understand hydraulic schematics.

1. Explain a logical sequence that should be followed when analyzing a large hydraulic schematic. (Intro.-2, 4)

2. What is the purpose of the 15–25-psi check valve that is located in the main reservoir return line? (8-2)

3. Explain what controls pressure buildup when using the auxiliary pump. (8-3)

4. What is the purpose of the selective relief valve as shown in figure 52? (8-3, 6; Fig. 52)

5. Explain the purpose of a bypass system. (8-7)

6. Why are remote-control (slave) valves often installed in large hydraulic systems? (8-8)

7. Why won't the nose gear mentioned in this section extend by "free-fall?" (9-1)

8. Do all landing gear selector valve handles have to be placed in neutral after an operation? (9-5)

9. Why is it necessary to apply hydraulic pressure to the landing gear uplatches prior to extending the gear? (9-7)

10. Can the landing gear be extended if hydraulic pressure is lost in flight? How? (9-9)

11. Explain the two methods of applying the brakes. (10-1)

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12. What maintenance procedure must be performed after using the emergency air brakes? (10-3)

13. What unit prevents accidental use of the steering system while the aircraft is airborne? (11-3)

14. What unit insures that both cargo door-latch actuators operate simultaneously? (11-7)

15. What unit limits the maximum travel of the wing flaps? (12-3)

16. What unit insures that the flaps will not move when in the intermediate position? (12-5)

17. What means is provided to allow manual control of the ailerons in the event system pressure is lost? (12-9)

18. What is the purpose of the priority valve installed between the aileron boost system and the inflight refueling sytem? (12-10)

*NOTE: Pages 409 and 410 are missing due to deleted material. No pertinent information was omitted.

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

1. To check new units for proper operation before installation, troubleshoot suspected inoperative units, and test overhauled or repaired units for proper operation.

2. To supply a controlled flow of fluid to the cylinder and component circuits.

3. The reservoir supplies fluid to all five circuits and contains 25 gallons.

4. The air comes from an external shop source and can be pressurized between 3 and 125 psi.

5. A suction switch turns off the electric motor which drives the pump.

6. It permits the operator to set the pump output to any selected flow to meet the test requirements of the units being tested.

7. This might cause damage to the seals.

8. The relief valve, which is preset to test specifications.

9. It will absorb pressure surges of the pump and units being tested.

10. To test engine-driven pumps.

11. A 6000-psi factory set nonadjustable relief valve.

12. The six test circuits are the five shown in figure 2: power pressure test, component test, cylinder test, pump test, foot pump or static test, and one other, the high-pressure air pump test.

13. To statically test components with pressure from 0 to 25,000 psi.

14. A float-type check valve.

15. Always position the range selector to send fluid to the larger flowmeter.

16. The fluid passes through a water-cooled heat exchanger before it enters the reservoir.

17. By cooling it with the heat exchanger or heating it with the reservoir heater, both of the temperature control circuit.

18. The accessory pressure gage.

19. It is for testing actuating cylinders and similar units where fluid flow occurs only until the mechanism reaches the end of its travel.

20. 2.5 to 25 gpm.

21. To test aircraft systems under conditions as close as possible to those of actual flight.

22. The engine pump(s).

23. *a.* Two independent systems.
    b. (1) To make operational checks of aircraft system.
    (2) To flush or fill the hydraulic systems.
    c. Together or separately.

24. The reservoir selector valve position.

25. The fill system relief valve.

26. To prevent immediate pressure buildup in the system, which would cause resistance to starting.

27. Bleed the stand.

28. You don't move it.

29. After initial setup, hose assemblies can be processed rapidly.

30. Be sure electric power is off.

31. Move switch to OFF, apply brake, and switch to REVERSE.

32. Read the TO for operation and safety instructions.

33. To determine the proper jack to be used, the location of the jack points, and the proper jacking procedures.

34. Height and capacity must be suitable.

35. To prevent a vacuum from being created while jacking.

36. The locknut.

37. Pump the ram up a short distance, then lay the jack on its side with the hose fitting up. Disconnect the hose and push the ram in slowly until all trapped air is expelled.

38. On top of the reservoir; it is also the air vent.

39. *a.* To adapt to different jack points of an aircraft.
    b. Reduce the possibility of a jack's slipping and damaging the aircraft.

40. The technical order of the aircraft being jacked for:

    a. placement of jacks.
    b. capacity of jacks needed.

41. To avoid damage from possible delayed aircraft strut compression.

42. To make it easier to get the jack from under the aircraft rapidly.

43. One man per jack and one "point" man to give directions.

44. Equal pressure resulting in even raising and lowering of all jacks.

45. Each time before you use it.

46. Base locks.

47. Place the U-shaped safety lock on the ram.

48. The amount of bypass valve opening.

49. 500 pounds.

50. Two—high and low systems.

51. Clutch takeoff.

52. The dehydrator or oxygen purifier cylinder.

53. It is used only up to 300 psi.

54. AFTO Form 45.

55. It is in the unload position and is adjusted to this position by turning the handle clockwise until the valve spring tension can first be felt, plus one full turn clockwise.

56. Be sure the exhaust gases are vented outside.

57. These are opened in order to discharge the air trapped in the servicing lines.

58. The hose could whip around and hurt you or someone else.

59. To clean filter elements, electronic parts, and mechanical units.

60. Piezoelectric and magnetrostrictive.

61. Physical and chemical.

62. Implosion.

63. The formation and bursting of the vapor pockets.

64. Yes, they will absorb some of the sonic energy.

65. Avoid breathing fumes of both carbon remover and trichloroethylene, and also avoid getting it on your skin.

66. The condensing coil converts the vapors to a liquid form.

67. Check for damage that would be beyond economical repair.

68. By performing the patch test.

69. *a.* There is a rupture at that point.
    b. If the bubbles appear, with a reading between 3" H_2O and the minimum allowed on the manometer, repair the element. If the reading is below 3" H_2O, the element is no good and is condemned. If bubbles appear above the minimum allowable reading, you do nothing, because the element is good.

70. Prevent recontamination and pack in clean plastic bags.

71. Three per cent.

CHAPTER 2

1. First, you should study the power section to determine how the pressure is developed and maintained. After this, you should follow the path of fluid flow through the pressure manifold to the various subsystems.

2. It insures a sufficient fluid flow through the venturi-tee for reservoir pressurization.

3. The auxiliary relief valve is designed to control maximum output of the auxiliary pump. It is located between the auxiliary pump and the system check valve. The selective relief valve determines where the first 1800 psi goes and then where the flow above 1800 psi goes.

4. It maintains 1800 psi fluid pressure for brake application.

5. The bypass system is designed to take much of the load off the engine pumps during long flights when there is little hydraulic action.

6. To keep large high-pressure lines out of the cockpit and to reduce the overall weight of the aircraft.

7. Because it extends forward into the slipstream.

8. No.

9. To reduce possible structural damage caused by the weight of the gear resting on the latches plus any hydraulic force exerted.

10. Yes, by manually releasing the uplatches and letting the main gear free-fall and applying maneuver techniques to extend the nose gear.

11. During normal operation the brakes are applied by pressure from the normal hydraulic system. The second method of operation is by the use of air pressure through an emergency air brake system.

12. The brakes have to be "bled" of air.

13. The oleo-actuated shutoff valve closes when the strut is extended, thus shutting off pressure to the steering control valve during flight.

14. Flow equalizer.

15. Wing flap limit valve.

16. The hydraulic brake on the hydraulic motor.

17. A spring-loaded plunger opens an interconnecting line between the two sides of the actuating piston.

18. To insure the aileron boost system has precedence over the inflight refueling system.

STOP–

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 1 PENCIL.

42152 04 25

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Use a clean eraser for any answer sheet changes, keeping erasures to a minimum.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

Multiple Choice

Chapter 1

1. (400) The suction supply circuit found in the HCT–6 hydraulic component tester provides the necessary fluid to how many test circuits?

   a. 3.
   b. 5.
   c. 7.
   d. 10.

2. (400) Whenever the filter becomes clogged the filter pressure switch causes the lamp on the panel to

   a. come on.
   b. go off.
   c. start flashing.
   d. activate a warning horn.

3. (400) The actuating test circuit selector valve on the HCT–6 test stand must be in the FLOWMETER RETURN position when you are adjusting the

   a. volume.
   b. pressure.
   c. relief valve.
   d. temperature controller.

4. (400) Which of the following units on the HCT–6 test stand measures the internal pump leakage of a pump under test?

   a. The leakage tank.
   b. The scavenge flowmeter.
   c. The 0.4 to 4 gpm flowmeter.
   d. The 2.5 to 25 gpm flowmeter.

5. (401) In order to speed the static tests of a large capacity unit on the HCT–6 test stand,

   a. a booster circuit is used.
   b. the unit is primed with a hand pump.
   c. an accumulator is used in the circuit.
   d. the unit is primed by using reservoir pressurization.

6. (401) To prevent the mercury from being blown out of the manometer of the HCT–6 hydraulic component test stand, the manometer circuit is equipped with

   a. an air bleed valve.
   b. a pump test suction shutoff valve.
   c. a float-type check valve.
   d. a pump test suction test port shutoff valve.

7. (401) A rotary-type vacuum pump is equipped with an automatic oiler that you would most correctly service with

   a. 20-weight engine oil.
   b. 30-weight engine oil.
   c. 40-weight engine oil.
   d. its own filtered fluid.

8. (402) If your were testing a hydraulic system on an aircraft with a high-flow requirement, what would you do with the MK-3?

   a. Increased the volume of the test stands pump.
   b. Add a boost pump to help the test stands pump.
   c. Manifold the No. 1 and No. 2 systems of the test stand together.
   d. Use a different test stand since you cannot adjust the pump.

9. (402) The MK-3 test stand automatically shuts down when the

   a. fluid gets too thick.
   b. suction filter becomes clogged.
   c. test stand reservoir is *not* at least 3/4 full.
   d. boost pressure to the main pump is less than 90 psig.

10. (402) If the fluid temperature in the MK-3 test stand becomes too high, the thermoswitch will

    a. sound a warning horn.
    b. turn on the fluid coolers.
    c. will not shut down the machine.
    d. indicate fluid temperature on the temperature gage.

11. (402) Before you connect the MK-3 test stand to the aircraft, you make certain that the

    a. electric plug to the power source is off.
    b. sight indicator lights are off.
    c. gage shutoff valves are set at one-fourth turn from fully opened.
    d. circuit breakers are on.

12. (402) In order to insure adequate power is available when you are to prestart both test stand systems.

    a. close both flow control vlaves.
    b. place one of the reservoir selector valves in STAND position.
    c. allow 1 minute delay before starting second system.
    d. place reservoir pressure dump valve to NEUTRAL position.

13. (403) The advantage of making hoses with the hose assembly machine over the hand method is that the machine

    a. can make any size hose assembly.
    b. can make size 2 through 48 medium-pressure hose assemblies.
    c. is used mainly for making hose assemblies using the flange-type fittings.
    d. can rapidly produce medium- or high-pressure hose assemblies within its limits.

14. (403) Before you assemble the fittings on a hose while using the hose assembly machine, you should insure that the

    a. brake is released.
    b. fittings are well lubricated.
    c. machine is set at 150 RPM.
    d. torque control box is set at 160 inch-pounds.

15. (403) The clearance between the "B" nut and sleeve on a hose assembly must be maintained to insure

    a. proper nipple alignment with connector.
    b. proper overall length of the hose assembly.
    c. that the "B" nut rotates freely during installation.
    d. that the hose is threaded into the sleeve correctly.

16. (404) The operator jacking an aircraft is having extreme difficulty operating the handle of the 6-ton tripod jack. If the capacity of the jack is adequate, he should next check

    a. the position of the handle fulcrum.
    b. the position of the needle valve.
    c. the grooves in the ram for cleanliness.
    d. for air under the ram.

17. (404) When an aircraft is raised with tripod jacks and one of the jacks settles down and lowers one wing, the most obvious cause of this is

    a. a defective ram seal that leaks.
    b. a leak in the pressure supply line hose.
    c. a leaking needle valve at the bottom of the reservoir.
    d. the locknut on the ram failed to lower into position.

18. (404) Axle jacks are often used instead of tripod jacks when

    a. one with a closed height of 6 inches is needed to raise the axle of the B–52 gear.
    b. tires are being repaired.
    c. a closed jack a little higher that the axle is required.
    d. brake work is not necessary.

19. (404) Jack pads are adapters used with aircraft jacks to

    a. give added distance in jacking.
    b. make it easier to position them.
    c. lessen the chance of damage to the aircraft.
    d. give a cushion between the jack and the aircraft.

20. (404) After the jacks have been properly placed, the *first* thing to do is to

    a. run the screw extension down the jack pad.
    b. tilt the jack to line up with the jack pad.
    c. close the needle valve as you start pumping.
    d. remove the wheel chocks.

21. (404) With regards to the use of any jack, you would most likely be correct if you

    a. always read the applicable TO before starting a job.
    b. rely on your general experience and common sense.
    c. listen to the advice of an old "pro" regarding jacking operations.
    d. know your job well enough to use short cuts.

22. (405) Before ascending to the platform of a B–1 maintenance stand, you must be sure that the

a. bypass valve is closed.
b. safety lock is installed.
c. ram locknut is screwed down tightly.
d. platform load will not exceed 500 pounds.

23. (405) The speed lowering a B–1 maintenance stand is controlled by the

a. hand pump.
b. bypass valve.
c. weight of the stand.
d. restrictor in the return line.

24. (405) What is the maximum *static* load a B–1 maintenance stand can support?

a. 600 pounds.
b. 100 pounds.
c. 1500 pounds.
d. 2000 pounds.

25. (406) The main purpose of the dehydrators on the air compressor is to

a. protect the purifier cartridge from excess moisture.
b. protect the compressor condensate chambers.
c. remove all condensation from the engine oil.
d. absorb remaining water vapor before the air enters the receiver.

26. (406) At what pressure does the pilot valve on the MC–1 air compressor automatically open to allow the pressure to pass to the blowdown valves?

a. 2400 psi.
b. 3200 psi.
c. 3500 psi.
d. 4000 psi.

27. (406) The oil levels for air compressors must be checked

a. prior to each start.
b. once every day.
c. twice a week.
d. weekly.

28. (406) In order to ease the compressor when you are starting operation of the MC–1, you make sure that the

a. pilot valve is in the manual load position.
b. pilot valve is in the manual unload position.
c. clutch is disengaged and positioned toward the instrument panel.
d. low-pressure regulator is completely turned clockwise.

29. (406) Normally, when you start the engine, you should *first*

a. see that the compressor hood is closed.
b. pull the ignition switch all the way out.
c. press the starter switch and hold the switch for 35 seconds.
d. pull the choke control part way out.

30. (406) To make your compressor last longer, you should observe all of the following rules *except*

    a. start the engine with the clutch disengaged.
    b. never engage the clutch when the engine is operating at speeds faster than fast idle.
    c. engage the clutch when the compressor controls are in the load position.
    d. never tighten the service line relief to exceed 35 inch-pounds.

31. (407) A sonic system on the SANE 50 ultra-sonic filter cleaner is composed of

    a. generator and transducer.
    b. battery and transducer.
    c. pump and vibrator.
    d. generator and sonic regulator.

32. (407) With reference to general safety precautions, the rule you would *least* likely to follow would be to

    a. always release the pressure in the service line before disconnecting it.
    b. treat a loose hose discharging high-pressure air as a dangerous weapon.
    c. encourage a little fun and play to break the monotony while performing your work.
    d. always be familiar with the TOs to ease workload.

33. (407) What is the proper sequence for cleaning filter elements in the SANE 50?

    a. Presoak, boil, cleaning, and test.
    b. Cleaning, presoak, boil, and test.
    c. Presoak, cleaning, boil, and condensate.
    d. cleaning, boil, condensate, and test.

34. (407) Which of the tanks in the SANE 50 have sonic units?

    a. Boil and cleaning tanks.
    b. Presoak and cleaning tanks.
    c. Condensate and test tanks.
    d. Presoak and test tanks.

35. (407) The element is still in the cleaning tank and the fluid has been circulated through the internal filters for 5 minutes. What is the next step?

    a. Immediately take ½ cup sample.
    b. Place the elements in the test tank.
    c. Agitate the elements for 3 minutes.
    d. Visually inspect the solid particles.

36. (407) While testing a clean filter element you notice a large column of bubbles coming from one point of the element; you know that

    a. the element is clean and ready for installation into a system.
    b. the element has met the maximum test standards and is serviceable.
    c. the element has met the minimum test standards and it is not serviceable.
    d. this area is damaged beyond repair if the bubbles appear before the manometer reads 3 inches of H_2O.

37. (408) If you are to properly troubleshoot hydraulic systems, you will find it *essential* to know how to

    a. interpret and apply schematics.
    b. locate applicable technical manuals.
    c. study in a logical and purposeful manner.
    d. put into practice your own ideas and work methods.

38. (408) On a routine ground check of a hydraulic system like the one shown in figure 23 of the text, while using the auxiliary electric pump you notice that the flight engineer's hydraulic pressure gage reads 1400 psi. This tells you that the

    a. brake system is fully pressurized.
    b. selective relief valve is closed.
    c. system is in the BYPASS position.
    d. main hydraulic system is still charged to 1400 psi.

39. (408) Refer to figure 23 of the text. When can the brake accumulator be used as a main system accumulator?

    a. Whenever the relief valve closes.
    b. When using the auxiliary pump.
    c. Whenever the system pressure is above 1400 psi.
    d. When system pressure is 1800 psi and above.

40. (408) Why is it desirable during long flights to relieve the load on the engine-driven pumps?

    a. To eliminate excessive loading and unloading of the pressure regulator.
    b. To eliminate the use of the bypass control valve in the bypass system.
    c. To help the crewmembers with an added safety element.
    d. To add corrective measures to minimum loading of the pressure regulator.

41. (409) Which of the following valves is *not* a remote control valve used to direct fluid pressure from the manifold to the actuators?

    a. Nose gear extension.
    b. Landing gear operating valve.
    c. Main gear retension valve.
    d. Emergency extension valve.

42. (409) When the landing gear selector valve is moved to the NORMAL DOWN position,

    a. the nose gear uplatch directs fluid pressure to the nose gear extension valve.
    b. fluid pressure is directed to the nose gear extension valve and the landing gear operating valve.
    c. the nose and main gears will be unlatched allowing them to free-fall to the EXTENDED position.
    d. fluid pressure is sent to the landing gear operating valve allowing this valve to direct fluid pressure to the three uplatches.

43. (409) In the event the landing gear fails to unlatch when the selector valve is moved to the NORMAL DOWN position, the uplatches may be released by

    a. moving the landing gear selector valve to the EMERGENCY DOWN position.
    b. first moving the selector valve to the UP position and then to the EMERGENCY DOWN position.
    c. reducing the airspeed, putting the aircraft in a shallow dive, and then moving the selector valve to the NORMAL DOWN position.
    d. pulling an emergency release handle located in the pilot's compartment.

44. (409) Refer to figure 25 of the text. What would be the most probable cause if, during landing, the right brake would not apply?

    a. The left shuttle valve was closed.
    b. The right hydraulic fuse was closed.
    c. The left hydraulic fuse was opened.
    d. The right shuttle valve was opened.

45. (409) You have just repaired a broken hydraulic brake line and during the checkout you find the brake operation erratic. What is the most probable cause?

    a. The brakes need to be bled.
    b. The PBCV is closing too soon.
    c. The hydraulic fuse is set.
    d. The shuttle valve is open.

46. (410) The nose gear is properly aligned for takeoff and landing by the

    a. torque links.
    b. weight of the nose gear.
    c. oleo-actuated valve.
    d. integral centering cams.

47. (410) The steering system shown in figure 26 of the text, provides a means for free-caster of the nosewheels in the event fluid pressure is lost. This is accomplished through the use of

    a. corotating wheels.
    b. a slide-type metering valve.
    c. control and followup cables.
    d. a balanced-type steering column.

48. (410) Refer to figure 27 of the text. When the cargo door selector valve is moved to the OPEN position, which of the following will happen?

    a. Pressure will close the latch actuators and open sequence valve B.
    b. Pressure will open the latch actuators causing sequence valve B to close.
    c. Pressure will open the latch actuators causing sequence valve B to open and allow the door to free-fall open.
    d. Pressure will open the latch actuators causing sequence valve B to open and direct hydraulic pressure to the open side of the door actuators.

49. (410) Refer to figure 27 of the text. When the door selector is moved to the CLOSED position

    a. sequence valve B is closed and sequence valve A is open.
    b. sequence valve B is open and sequence valve A is closed.
    c. the sequence valves are automatically opened.
    d. both sequence valves are closed.

50. (410) The hydraulic motor brake is released by

a. pressure from the wing flaps lock valve.
b. pressure from the wing flap control valves.
c. mechanical linkage from the wing flap limit valve.
d. mechanical linkage from the wing flap control valve.

51. (410) Refer to figure 28 of the text. The constant flow valve insures that the flaps

a. extend and retract at varying speeds.
b. extend and retract at the same speed.
c. extend fast and retract slow.
d. extend slow and retract fast.

52. (410) When the pilot positions the slide valve to the right, pressure moves the

a. piston to the right.
b. piston to the left.
c. housing assembly to the left.
d. entire housing to the right.

53. (410) In the event hydraulic pressure is lost, the ailerons can be controlled by

a. mechanical means.
b. the air load on the surfaces.
c. the auxiliary pump pressure.
d. pressure trapped in the cylinder.

54. (410) The priority valve installed in the pressure line insures the

a. inflight refueling system has priority over the ailerons.
b. ailerons can operate after pressure builds up to 2500 psi.
c. inflight refueling systems can operate after pressure builds up to 1800 psi.
d. ailerons have priority over the inflight refueling system.

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MODIFICATIONS

Pages 26-27 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.